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FORESTRY FOR FARMERS.

BY

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF FORESTRY,
Washington, D. C., December 4, 1897.

SIR: I have the honor to recommend that the two articles contributed by me to the Yearbooks for 1894 and for 1895 on forestry for farmers be reprinted as a Farmers' Bulletin. The articles contain information in popular form regarding the growth of trees, the planting of a forest, treatment of the wood lot, the cultivation of the wood crop, influence of trees, etc. A wider distribution of this information, for which there is still considerable demand, would, I believe, result in acquainting farmers with a subject the importance of which has not always been duly recognized.

Very respectfully,

B. E. FERNOW, *Chief.*

Approved:

JAMES WILSON, *Secretary.*

CONTENTS.

FORESTRY FOR FARMERS.

The following five chapters have been written with the view of aiding farmers who own small timber tracts or wood lots, or who wish to plant some part of their land to forest. This country varies so greatly in soil, climate, and flora that it is only possible, within the limits assigned for the present discussion, to outline general principles everywhere applicable. Nevertheless, wherever suggestions have approximated the laying down of rules of practice, the writer has had mainly in mind the conditions prevalent in our northeastern States. Moreover, for the reason already referred to, limitation of space, it has not been possible to give more than a comprehensive view, without much detail.

The succeeding chapters should be read connectedly, as they are more or less interdependent. The first treats of the behavior of a forest plant; the second, of the principles which should guide the planter in setting a crop; the third, of the manner in which a natural forest crop should be produced; the fourth points out how the crop should be managed afterwards in order to secure the best results in quantity and quality of material; while the fifth chapter is devoted to a consideration of the relation of forests to farms.

1. HOW TREES GROW.

Trees, like most other plants, originate from seed, build up a body of cell tissues, form foliage, flower, and fruit, and take up food material from the soil and air, which they convert into cellulose and other compounds, from which all their parts are formed. They rely, like other plants, upon moisture, heat, and light as the means of performing the functions of growth. Yet there are some peculiarities in their behavior, their life and growth, which require special attention on the part of a tree grower or forest planter, and these we shall briefly discuss.

FOOD MATERIALS AND CONDITIONS OF GROWTH.

Trees derive their food and solid substance in part from the air and in part from the soil. The solid part of their bodies is made up of cellulose, which consists largely of carbon (44 per cent of its weight), with hydrogen and oxygen added in almost the same proportions as in water. The carbon is derived from the carbonic acid of the air, which

enters into the leaves and, under the influence of light, air, and water, is there decomposed; the oxygen is exhaled; the carbon is retained and combined with elements derived from the water, forming compounds, such as starch, sugar, etc., which are used as food materials, passing down the tree through its outer layers to the very tips of the roots, making new wood all along the branches, trunk, and roots.

This process of food preparation, called "assimilation," can be carried on only in the green parts, and in these only when exposed to light and air; hence foliage, air, and light at the top are essential prerequisites for tree growth, and hence, other conditions being favorable, the more foliage and the better developed it is, and the more light this foliage has at its disposal for its work, the more vigorously will the tree grow.

In general, therefore, pruning, since it reduces the amount of foliage, reduces also, for the time, the amount of wood formed; and just so shading, reducing the activity of foliage, reduces the growth of wood.

SOIL CONDITIONS.

From the soil trees take mainly water, which enters through the roots and is carried through the younger part of the tree to the leaves, to be used in part on its passage for food and wood formation and in part to be given up to the air by transpiration.

In a vigorously growing tree the solid wood substance itself will contain half its weight in the form of water chemically combined, and the tree, in addition, will contain from 40 to 65 per cent and more of its dry weight in water mechanically or "hygroscopically" held. This last, when the tree is cut, very largely evaporates; yet well-seasoned wood still contains 10 to 12 per cent of such water. The weight of a green tree, a pine, for instance, is made up, in round numbers, of about 30 per cent of carbon and 70 per cent of water, either chemically or hygroscopically held, while a birch contains a still larger percentage of water.

The largest part of the water which passes through the tree is transpired—i. e., given off to the air in vapor. The amounts thus transpired during the season vary greatly with the species of tree, its age, the amount of foliage at work, the amount of light at its disposal, the climatic conditions (rain, temperature, winds, relative humidity), and the season. These amounts are, however, very large when compared with the quantity retained; so that while an acre of forest may store in its trees, say, 1,000 pounds of carbon, 15 to 20 pounds of mineral substances, and 5,000 pounds of water in a year, it will have transpired—taken up from the soil and returned to the air—from 500,000 to 1,500,000 pounds of water (one-quarter to one-half as much as agricultural crops).

Mineral substances are taken up only in very small quantities, and these are mostly the commoner sorts, such as lime, potash, magnesia, and nitrogen. These are carried in solution to the leaves, where they are used (as perhaps also on their passage through the tree), with a

part of the water, in food preparation. The main part of the mineral substances taken up remains, however, as the water transpires, in the leaves and young twigs, and is returned to the soil when the leaves are shed or when the tree is cut and the brush left to decompose and make humus.

Hence the improvement of the fertility of the soil by wood crops is explained, the minerals being returned in more soluble form to the soil; as also the fact that wood crops do not exhaust the soil of its minerals, provided the leaves and litter are allowed to remain on the ground.

For this reason there is no necessity of alternating wood crops, as far as their mineral needs are concerned; the same kind of trees can be grown on the same soil continuously, provided the soil is not allowed to deteriorate from other causes.

As the foliage can perform its work of food assimilation only when sufficient water is at its disposal, the amount of growth is also dependent not only on the presence of sufficient sources of supply, but also on the opportunity had by the roots to utilize the supply, and this opportunity is dependent upon the condition of the soil. If the soil is compact, so that the rain water can not penetrate readily, and runs off superficially, or if it is of coarse grain and so deep that the water rapidly sinks out of reach of the roots and can not be drawn up by capillary action, the water supply is of no avail to the plants; but if the soil is porous and moderately deep (depth being the distance from the surface to the impenetrable subsoil, rock, or ground water) the water not only can penetrate but also can readily be reached and taken up by the roots.

The moisture of the soil being the most important element in it for tree growth, the greatest attention must be given to its conservation and most advantageous distribution through the soil.

No trees grow to the best advantage in very dry or very wet soil, although some can live and almost thrive in such unfavorable situations. A moderately but evenly moist soil, porous and deep enough or fissured enough to be well drained, and yet of such a structure that the water supplies from the depths can readily be drawn up and become available to the roots—that is the soil on which all trees grow most thriftily.

The agriculturist procures this condition of the soil as far as possible by plowing, drainage, and irrigation, and he tries by cultivating to keep the soil from compacting again, as it does under the influence of the beating rain and of the drying out of the upper layers by sun and wind.

The forest grower can not rely upon such methods, because they are either too expensive or entirely impracticable. He may, indeed, plow for his first planting, and cultivate the young trees, but in a few years this last operation will become impossible and the effects of the first operation will be lost. He must, therefore, attain his object in another manner, namely, by shading and mulching the soil. The shading is

done at first by planting very closely, so that the ground may be protected as soon as possible from sun and wind, and by maintaining the shade well throughout the period of growth. This shade is maintained, if necessary, by more planting, and in case the main crop in later life thins out inordinately in the crowns or tops, or by the accidental death of trees, it may even become desirable to introduce an underbrush.

The mulching is done by allowing the fallen leaves and twigs to remain and decay, and form a cover of rich mold or humus. This protective cover permits the rain and snow waters to penetrate without at the same time compacting the soil, keeping it granular and in best condition for conducting water, and at the same time preventing evaporation at the surface.

The soil moisture, therefore, is best maintained by proper soil cover, which, however, is needful only in naturally dry soils. Wet soils, although supporting tree growth, do not, if constantly wet, produce satisfactory wood crops, the growth being very slow. Hence they must be drained and their water level sunk below the depth of the root system.

Irrigation is generally too expensive to be applied to wood crops, except perhaps in the arid regions, where the benefit of the shelter belt may warrant the expense.

Attention to favorable moisture conditions in the soil requires the selection of such kinds of trees as shade well for a long time, to plant closely, to protect the woody undergrowth (but not weeds), and to leave the litter on the ground as a mulch.

Different species, to be sure, adapt themselves to different degrees of soil moisture, and the crop should therefore be selected with reference to its adaptation to available moisture supplies.

While, as stated, all trees thrive best with a moderate and even supply of moisture, some can get along with very little, like the conifers, especially pines; others can exist even with an excessive supply, as the bald cypress, honey locust, some oaks, etc. The climate, however, must also be considered in this connection, for a tree species, although succeeding well enough on a dry soil in an atmosphere which does not require much transpiration, may not do so in a drier climate on the same soil.

In the selection of different kinds of trees for different soils, the water conditions of the soil should, therefore, determine the choice.

LIGHT CONDITIONS.

To insure the largest amount of growth, full enjoyment of sunlight is needed. But as light is almost always accompanied by heat and relative dryness of air, which demands water from the plant, and may increase transpiration from the leaves inordinately, making them pump too hard, as it were, young seedlings of tree species whose foliage is not built for such strains require partial shading for the first year or two. The conifers belong to this class.

In later life the light conditions exert a threefold influence on the development of the tree, namely, with reference to soil conditions, with reference to form development, and with reference to amount of growth.

The art of the forester consists in regulating the light conditions so as to secure the full benefit of the stimulating effect of light on growth, without its deteriorating influences on the soil and on form development.

As we have seen, shade is desirable in order to preserve soil moisture. Now, while young trees of all kinds, during the "brush" stage of development, have a rather dense foliage, as they grow older they vary in habit, especially when growing in the forest. Some, like the beech, the sugar maple, the hemlock, and the spruce, keep up a dense crown; others, like the chestnut, the oaks, the walnut, the tulip tree, and the white pine, thin out more and more, and when fully grown have a much less dense foliage; finally, there are some which do not keep up a dense shade for any length of time, like the black and honey locust, with their small, thin leaves; the catalpa, with its large but few leaves at the end of the branchlets only, and the larch, with its short, scattered bunches of needles. So we can establish a comparative scale of trees with reference to the amount of shade which they can give continuously, as densely foliaged and thinly foliaged, in various gradations. If we planted all beech or sugar maple, the desirable shading of the soil would never be lacking, while if we planted all locust or catalpa the sun would soon reach the soil and dry it out, or permit a growth of grass or weeds, which is worse, because these transpire still larger quantities of water than the bare ground evaporates or an undergrowth of woody plants would transpire. Of course, a densely foliaged tree has many more leaves to shed than a thinly foliaged one, and therefore makes more litter, which increases the favorable mulch cover of the soil. Another reason for keeping the ground well shaded is that the litter then decomposes slowly, but into a desirable humus, which acts favorably upon the soil, while if the litter is exposed to light, an undesirable, partly decomposed "raw" humus is apt to be formed.

Favorable soil conditions, then, require shade, while wood growth is increased by full enjoyment of light; to satisfy both requirements, mixed planting, with proper selection of shade-enduring and light-needing species, is resorted to.

As the different species afford shade in different degrees, so they require for their development different degrees of light. The dense foliage of the beech, with a large number of leaves in the interior of the crown, proves that the leaves can exist and perform their work with a small amount of light; the beech is a shade-enduring tree. The scanty foliage of the birches, poplars, or pines shows that these are light-needing trees; hence they are never found under the dense shade of the former, while the shade-enduring can develop satisfactorily

under the light shade of the thin-foliaged kinds. Very favorable soil conditions increase the shade endurance of the latter, and climatic conditions also modify their relative position in the scale.

All trees ultimately thrive best—i. e., grow most vigorously—in the full enjoyment of light, but their energy then goes into branching. Crowded together, with the side light cut off, the lower lateral branches soon die and fall, while the main energy of growth is put into the shaft and the height growth is stimulated. The denser shade of the shade-enduring kinds, if placed as neighbors to light-needing ones, is most effective in producing this result, provided that the light is not cut off at the top; and thus, in practice, advantage is taken of the relative requirements for light of the various species.[1]

The forester finds in close planting and in mixed growth a means of securing tall, clear trunks, free from knots, and he is able, moreover, by proper regulation of light conditions, to influence the form development, and also the quality of his crop, since slow growth and rapid growth produce wood of different character.

There are some species which, although light foliaged and giving comparatively little shade, are yet shade enduring—i. e., can subsist, although not develop favorably, under shade; the oaks are examples of this kind. Others, like the black cherry, bear a dense crown for the first twenty years, perhaps, seemingly indicating great shade endurance; but the fact that the species named soon clears itself of its branches and finally has a thin crown, indicates that it is light needing, though a good shader for the first period of its life. Others, again, like the catalpa, which is shady and shade enduring, as the difficulty with which it clears itself indicates, leaf out so late and lose their foliage so early that their shading value is thereby impaired. Black locust and honey locust, on the other hand, leave no doubt either as to their light-needing or their inferior shading quality.

That soil conditions and climatic conditions also modify crown development and shade endurance has been well recognized abroad, but in our country this influence is of much more importance on account of the great variation in those conditions. Thus the box elder, an excellent shader in certain portions of the West, is a failure as soil cover in others where it nevertheless will grow.

We see, then, that in determining the shading value as well as the shade endurance of one species in comparison with another, with reference to forestry purposes, not only soil and climate but also the character of foliage and its length of season must be considered.

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[1]This relation of the different species to varying light conditions, their comparative shading value and shade endurance, is one of the most important facts to be observed and utilized by the forester. European foresters have done this, but since they had to deal with only a few species and over a limited territory, they could quite readily classify their trees with reference to their shade endurance, and take it for granted that shade endurance and density of foliage or shading value were more or less identical. With our great wealth of useful species it will be necessary and profitable to be more exact in the classification.

PHYSIOLOGY OF TREE GROWTH.

As we have seen, root and foliage are the main life organs of the tree. The trunk and branches serve to carry the crown upward and expose it to the light, which is necessary in order to prepare the food and increase the volume of the tree, and also as conductors of food materials up and down between root and foliage. A large part of the roots, too, aside from giving stability to the tree, serve only as conductors of water and food material; only the youngest parts, the fibrous roots, beset with innumerable fine hairs, serve to take up the water and minerals from the soil. These fine roots, root hairs, and young parts are therefore the essential portion of the root system. A tree may have a fine, vigorous-looking root system, yet if the young parts and fibrous roots are cut off or allowed to dry out, which they readily do—some kinds more so than others—thereby losing their power to take up water, such a tree is apt to die. Under very favorable moisture and temperature conditions, however, the old roots may throw out new sprouts and replace the fibrous roots. Some species, like the willows, poplars, locusts, and others, are especially capable of doing so. All trees that "transplant easily" probably possess this capacity of renewing the fibrous roots readily, or else are less subject to drying out. But it may be stated as a probable fact that most transplanted trees which die soon after the planting do so because the fibrous roots have been curtailed too much in taking up, or else have been allowed to dry out on the way from the nursery or forest to the place of planting; they were really dead before being set. Conifers—pines, spruces, etc.—are especially sensitive; maples, oaks, catalpas, and apples will, in this respect, stand a good deal of abuse.

Hence, in transplanting, the first and foremost care of the forest grower, besides taking the sapling up with least injury, is the proper protection of its root fibers against drying out.

The water, with the minerals in solution, is taken up by the roots when the soil is warm enough, but to enable the roots to act they must be closely packed with the soil. It is conveyed mostly through the outer, which are the younger, layers of the wood of root, trunk, and branches to the leaves. Here, as we have seen, under the influence of light and heat it is in large part transpired and in part combined with the carbon into organic compounds, sugar, etc., which serve as food materials. These travel from the leaf into the branchlet, and down through the outer layers of the trunk to the very tips of the root, forming new wood all the way, new buds, which lengthen into shoots, leaves, and flowers, and also new rootlets. To live and grow, therefore, the roots need the food elaborated in the leaves, just as the leaves need the water sent up from the roots.

Hence the interdependence of root system and crown, which must be kept in proportion when transplanting. At least, the root system must be sufficient to supply the needs of the crown.

"SAP UP AND SAP DOWN."

The growing tree, in all its parts, is more or less saturated with water, and as the leaves, under the influence of sun and wind and atmospheric conditions generally transpire, new supplies are taken in through the roots and conveyed to the crown. This movement takes place even in winter, in a slight degree, to supply the loss of water by evaporation from the branches. In the growing season it is so active as to become noticeable; hence the saying that the sap is "up," or "rising," and when, toward the end of the season, the movement becomes less, the sap is said to be "down." But this movement of water is always upward; hence the notion that there is a stream upward at one season and in one part of the tree, and a stream downward at another season and perhaps in another part of the tree, is erroneous. The downward movement is of food materials, and the two movements of water upward and food downward take place simultaneously, and depend, in part at least, one upon the other, the food being carried to the young parts, wherever required, by a process of diffusion from cell to cell known as "osmosis."

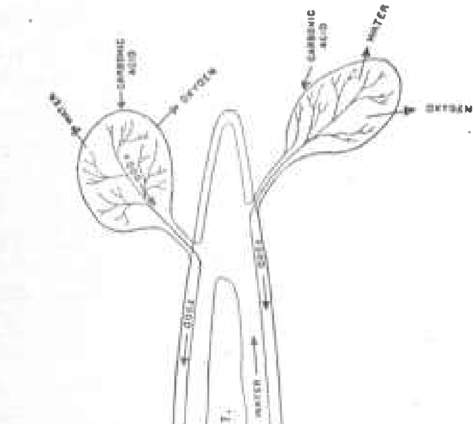


FIG. 1.—Physiological importance of different parts of the tree; pathways of water and food materials. (Schematic.)

These food materials are, by the life processes of the active cells, changed in chemical composition as need be, from sugar, which is soluble, into starch, which is insoluble, and back into sugar, and combined with nitrogenous substances to make the cell-forming material, protoplasm (fig. 1).

In the fall, when the leaves cease to elaborate food, both the upward and the downward movement, more or less simultaneously, come to rest (the surplus of food materials, as starch, and sometimes as sugar, being stored for the winter in certain cell tissues), to begin again simultaneously when in spring the temperature is high enough to reawaken

activity, when the stored food of last year is dissolved and started on its voyage. The exact manner in which this movement of water upward and food materials downward takes place, and the forces at work, are not yet fully understood, nor is there absolute certainty as to the parts of the tree in which the movement takes place. It appears, however, that while all the so-called "sapwood" is capable of conducting water (the heartwood is probably not), the most active movement of both water and food materials takes place in the cambium (the growing cells immediately beneath the bark) and youngest parts of the bark.

The deductions from these processes important to the planter are: That injury to the living bark or bast means injury to growth, if not destruction to life; that during the period of vegetation transplanting can be done only with great caution; that the best time to move trees is in the fall, when the leaves have dropped and the movement of water and food materials has mostly ceased, or in spring, before the movement begins again, the winter being objectionable only because of the difficulty of working the soil and of keeping the roots protected against frost. All things considered, spring planting, before activity in the tree has begun, is the best, although it is not impossible to plant at other times.

PROGRESS OF DEVELOPMENT.

Like the wheat or corn plant, the tree seed require as conditions for sprouting sufficient moisture, warmth, and air. Tree seeds, however, differ from grain in that most of the kinds lose their power of germination easily; with few exceptions (locust, pine, spruce), they can not be kept for any length of time.

The first leaves formed often differ essentially in shape from those of the mature tree, which may cause their being confounded with other plants, weeds, etc.

The little seedlings of many, especially the conifers, are quite delicate, and remain very small the first season; they need, therefore, the protecting shade of mother trees, or artificial shading, and also protection against weeds. The amount of light or shade given requires careful regulation for some of them; too much light and heat will kill them, and so will too much shade. This accounts for the failure of many seedlings that spring up in the virgin forest.

The planter, then, is required to know the nature and the needs of the various kinds of seeds and seedlings, so as to provide favorable conditions, when he will avoid sowing in the open field such as require the care which it is impracticable to give outside of the nursery.

GROWTH IN LENGTH AND RAMIFICATION.

While the stalk of wheat or corn grows for one season, exhausts itself in seed production, and then dies, the tree continues to grow from season to season, in length as well as in thickness. The growth

in length of shaft and branches proceeds from buds, made up of cell tissues, which can subdivide and lengthen into shoots, as well as make leaves. These buds are formed during summer, and when winter begins contain embryo leaves, more or less developed, under the protecting cover of scales (fig. 3). When spring stimulates the young plant to new activity, the buds swell, shed their scales, dis-

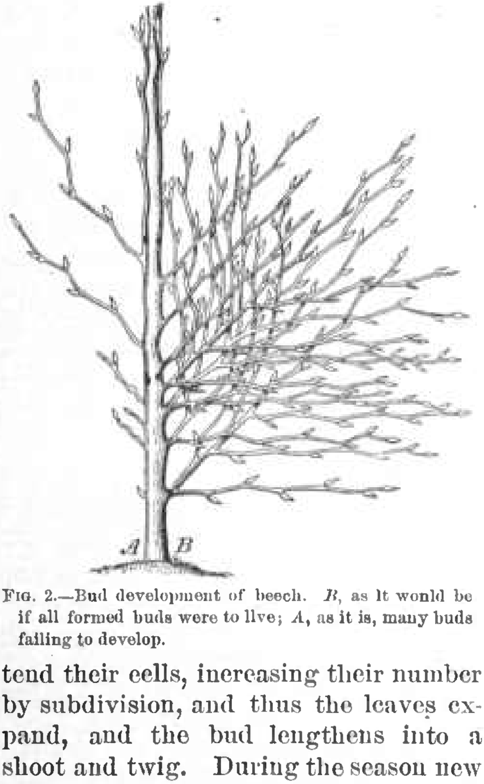


FIG. 2.—Bud development of beech. *B*, as it would be if all formed buds were to live; *A*, as it is, many buds failing to develop.

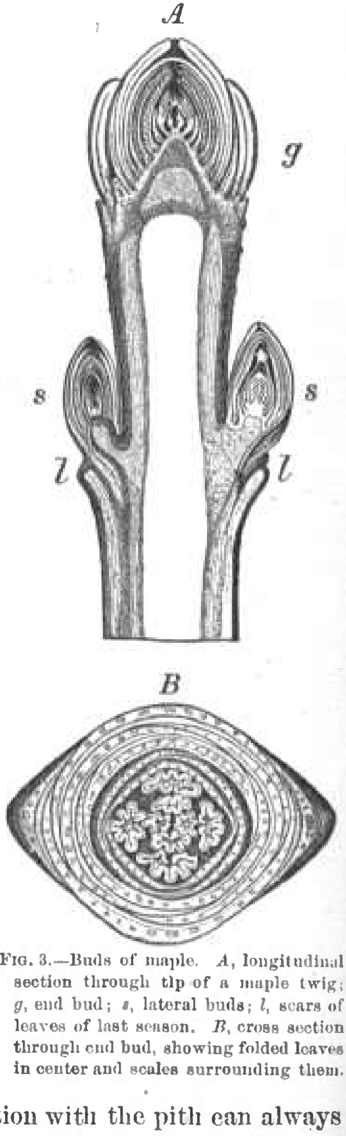


FIG. 3.—Buds of maple. *A*, longitudinal section through tip of a maple twig; *g*, end bud; *s*, lateral buds; *l*, scars of leaves of last season. *B*, cross section through end bud, showing folded leaves in center and scales surrounding them.

tend their cells, increasing their number by subdivision, and thus the leaves expand, and the bud lengthens into a shoot and twig. During the season new buds are formed, and the whole process repeats itself from year to year, giving rise to the ramification and height growth of the tree. The end buds being mostly stronger and better developed, the main axis of tree or branch increases more rapidly than the rest. All these buds originate from the youngest, central part of the shoot, the pith, and hence when the tree grows in thickness, enveloping the base of the limbs, their connection with the pith can always be traced. This is the usual manner of bud formation; in addition, so-called "adventitious" buds may be formed from the young living wood in later life, which are not connected with the pith. Such buds are those which develop into sprouts from the stump when the tree is

cut; also those which give rise to what are known as "water sprouts." Many buds, although formed, are, however, not developed at once, and perhaps not at all, especially as the tree grows older; these either die or remain "dormant," often for a hundred years, to spring into life when necessary (fig. 4).

The fact that each ordinary limb starts as a bud from the pith is an important one to the timber grower; it explains knotty timber and gives him the hint that in order to obtain clear timber the branches

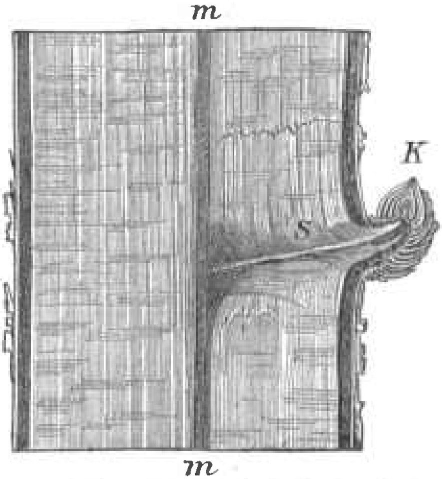


FIG. 4.—Dormant bud, *K*, on a 12-year old branch of beech. The bud is still capable of development and is connected with the pith, *mm*, of the stem by a fine trace of pith, *S*.

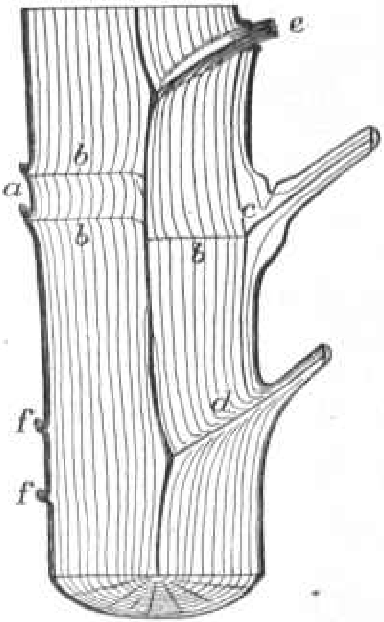


FIG. 5.—Section through a 12-year old stem of beech, showing manner of bud and limb formation. *a*, dormant buds; *b*, their trace of pith extending to the pith of the stem; *c*, a limb which started two years ago from a dormant bud; *d*, normal limb; *e*, a limb dead for four years; *f*, adventitious buds.

first formed must be soon removed, either by the knife or by proper shading, which kills the branches and thus "clears" the shaft.

The planter has it also in his power to influence the form development of the tree by removing some of the buds, giving thereby better chance to the remaining ones. This pruning of buds is, where practicable, often better practice than the pruning of limbs.

Since the tree does not grow in length except by its buds it is evident that a limb which started to grow at the height of 6 feet has its base always 6 feet from the ground, and if allowed to grow to size, must be surrounded by the wood which accumulates on the main stem or trunk. If a limb is killed and broken off early, only a slender stub composed entirely of rapidly decaying sapwood, is left, occasioning, therefore, only a small defect in the heart of the tree; but if left to grow to considerable age, the base of the limb is incased by the wood of the stem, which, when the tree is cut into lumber, appears as a knot.

The longer the limb has been allowed to grow, the farther out is the timber knotty and the thicker is the knot. If the limb remained alive, the knot is "sound," closely grown together with the fibers of the tree. If the limb died off, the remaining stub may behave in different ways. In pines it will be largely composed of heartwood, very resinous and durable; separated from the fibers of the overgrowing wood, it forms a "loose" knot, which is apt to fall out of a board, leaving a hole.

In broad-leaved trees, where no resin assists in the process of healing, the stub is apt to decay, and this decay, caused by the growth of fungi, is apt to penetrate into the tree (fig. 6). In parks and orchards, pruning is resorted to, and the cuts are painted or tarred to avoid the decay. In well-managed forests and dense woods in general, the light is cut off, the limb is killed when young and breaks away, the shaft "clears itself," and the sound trunk furnishes a good grade of material. The difference in development of the branch system, whether in full enjoyment of light, in open stand, or with the side light cut off, in dense position, is shown in the accompanying illustration (fig. 7).

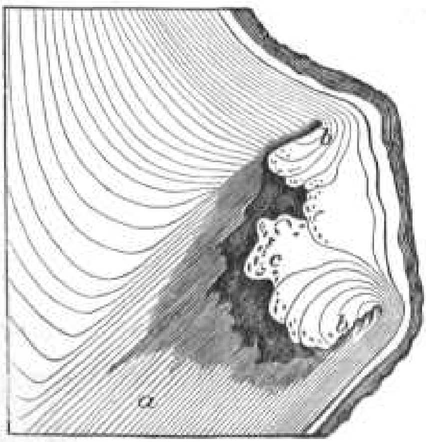


FIG. 6.—Section through a partly decayed knot in oak wood. *a*, wood of the knot; *b* and *c*, wood callus of the stem covering the wound; shaded portion, decayed wood; black part, a cavity remaining.

Both trees start alike; the one retains its branches, the other loses them gradually, the stubs being in time overgrown; finally the second has a clear shaft, with a crown concentrated at the top, while the first is beset with branches and branch stubs for its whole length (fig. 8).

When ripped open lengthwise, the interior exhibits the condition shown in figure 9, the dead parts of the knot being indicated in heavier shading. Since the branches grow in more or less regular whorls, several knots, stumps, or limbs are met every 6 to 24 inches through the entire stem.

Hence, in forest planting, trees are placed and kept for some time close together, in order to decrease the branching in the lower part of the tree and thus produce a clean bole and clear lumber.

GROWTH IN THICKNESS.

The young seedling and the young shoot of the older tree much resemble in interior structure that of any herbaceous plant, being composed of a large amount of pith, loose squarish cells, and a few bundles of long fibers symmetrically distributed about the center, the whole covered with a thin skin or epidermis. Each strand or bundle of

fibers, called fibro-vascular (fiber-vessel) bundles, consists of two kinds, namely, wood fibers on the inner side and bast fibers of different structure on the outer side. Between these two sets of fibers, the bast and the wood, there is a row of cells which form the really active, growing part of the plantlet, the cambium. The cambium cells are actively subdividing and expanding, giving off wood cells to the interior and bast cells to the exterior, and extending at the same time sidewise, until at the end of the season not only are the wood and bast portions increased in lines radiating from the center, but the cambium layer, the wood cells, and the bast cells of all the bundles (scattered at the beginning) join at the sides to form a complete ring, or rather hollow cylinder, around the central pith. Only here and there the pith cells remain, interrupting the wood cylinder and giving rise to the system of cells known as medullary rays. The cross section now shows a comparatively small amount of pith and bast or bark and a larger body of strong wood fibers. The new shoot at the end, to be sure, has the same appearance and arrangement as the young plantlet had, the pith preponderating, and the continuous cylinder of cambium, bast, and wood being separated into strands or bundles.

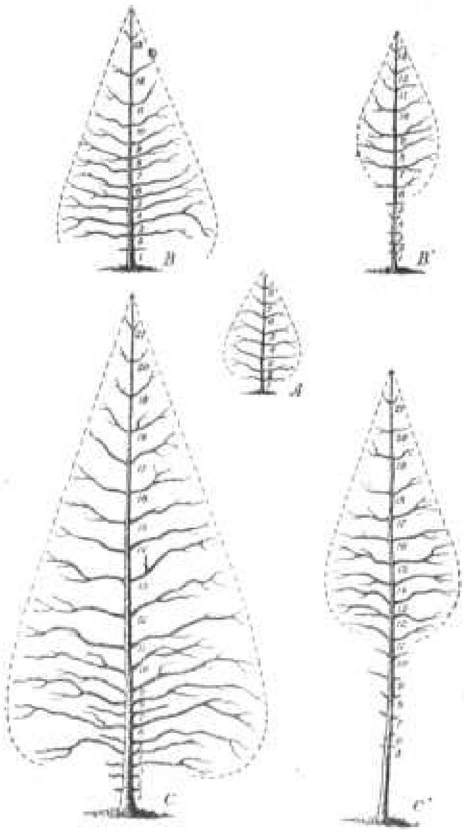


FIG. 7.—Development in and out of the forest. *A*, young tree alike in both cases; *B* and *C*, successive stages of tree grown in the open; *B'* and *C'*, corresponding stages of the tree grown in the forest. Numbers refer to annual growth in height.

During the season, through the activity of the cambial part of the bundles, the same changes take place in the new shoot as did the previous year in the young seedling, while at the same time the cambium in the yearling part also actively subdivides, forming new wood and bast cells, and thus a second ring, or rather cylinder, is formed. The cambium of the young shoot is always a continuation of that of the ring or cylinder formed the year before, and this cambium cylinder always keeps moving outward, so that at the end of the season, when activity ceases, it is always the last minute layer of cells on the outside of the wood, between wood proper and

bark. It is here, therefore, that the life of the tree lies, and any injury to the cambium must interfere with the growth and life of the tree.

The first wood cells which the cambium forms in the spring are usually or always of a more open structure, thin walled, and with a large opening or "lumen," comparable to a blown-up paper bag; so large, in fact, sometimes, is the "lumen" that the width of the cells can be seen on a cross section with the naked eye, as, for instance, in oak, ash, elm, the so-called "pores" are this open wood formed in spring. The cells, which are formed later in summer, have mostly thick walls, are closely crowded and compressed, and show a very small opening or "lumen," being comparable, perhaps, to a very thick wooden box. They appear in the cross section not only denser but of a deeper color, on account of their crowded, compressed condition and thicker walls. Since at the beginning of the next season again thin-walled cells with wide openings or lumina are formed, this difference in the appearance of "spring wood" and "summer wood" enables us to distinguish the layer of wood formed each year. This "annual ring" is more conspicuous in some kinds than in others. In the so-called "ring porous" woods, like oak, ash, elm, the rings are easily distinguished by the open spring wood; in the conifers, especially pines, by the dark-colored summer wood; while in maple, birch, tulip, etc., only a thin line of flattened, hence darker and regularly aligned, summer cells, often hardly recognizable, distinguishes the rings from each other. Cutting through a tree, therefore, we can not only ascertain its age by counting its annual layers in the cross section, but also determine how much wood is formed each year (fig. 10). We

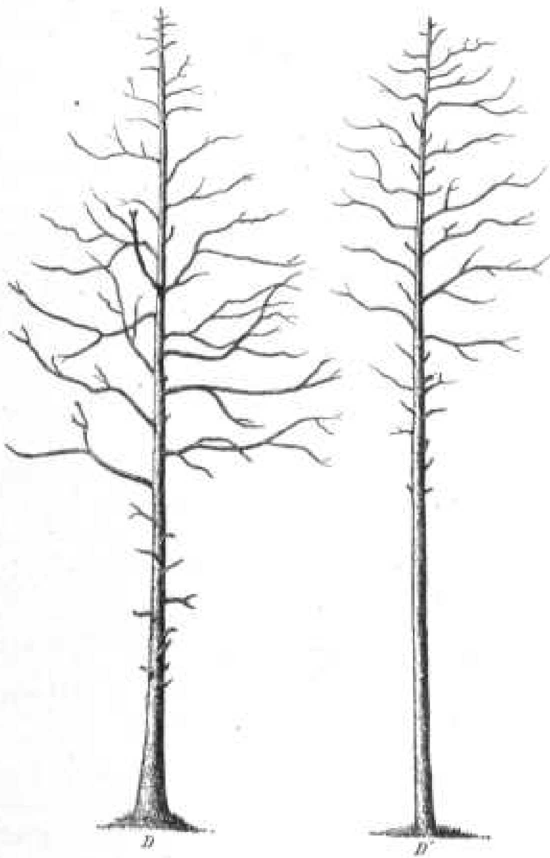


FIG. 8.—Trees in and out of the forest. *D*, tree grown in the open; *D'*, tree grown in the forest.

can, in fact, retrace the history of its growth, the vicissitudes through which it has passed, by the record preserved in its ring growth.

To ascertain the age of a tree correctly, however, we must cut so near to the ground as to include the growth of the first year's little plantlet; any section higher up shows as many years too few as it took the tree to reach that height.

This annual-ring formation is the rule in all countries which have distinct seasons of summer and winter and temporary cessation of growth. Only exceptionally a tree may fail to make its growth throughout its whole length on account of loss of foliage or other causes; and occasionally, when its growth has been disturbed during the season, a "secondary" ring, resembling the annual ring, and distinguishable only by the expert, may appear and mar the record.

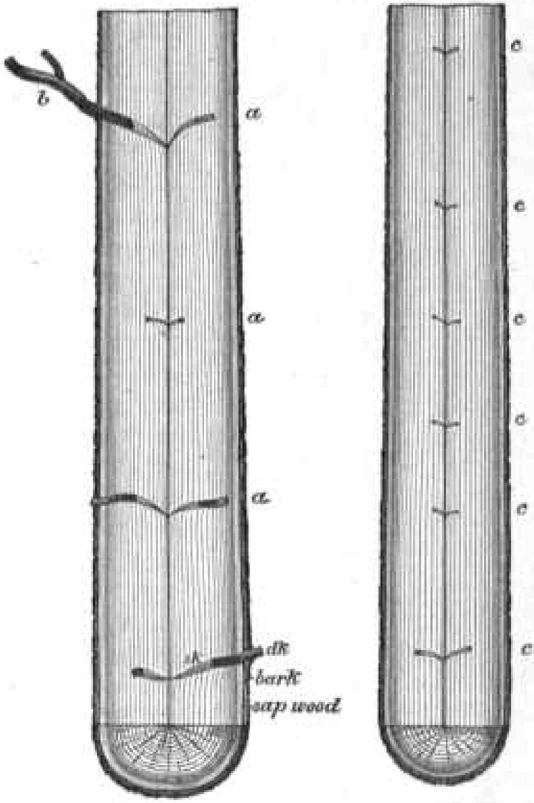


FIG. 9.—Sections of logs showing the relative development of knots. *E*, from tree grown in the open; *E'*, from tree grown in a dense forest; *a* and *c*, whorls of knots; *b*, dead limb; *sk*, "sound knot;" *dk*, "dead knot."

To the forest planter this chapter on ring growth is of great importance, because not only does this feature of tree life afford the means of watching the progress of his crop, calculating the amount of wood formed, and therefrom determining when it is most profitable for him to harvest (namely, when the annual or periodic wood growth falls below a certain amount), but since the proportion of summer wood and spring wood determines largely the quality of the timber, and since he has it in his power to influence the preponderance of the one or other by adaptation of species to soils and by their management, ring growth furnishes an index for regulating the quality of his crop.

FORM DEVELOPMENT.

If a tree is allowed to grow in the open, it has a tendency to branch, and makes a low and spreading crown. In order to lengthen its shaft and to reduce the number of branches it is necessary to narrow its

growing space, to shade its sides so that the lower branches and their foliage do not receive light enough to perform their functions. When the side shade is dense enough, these branches die and finally break off under the influence of winds and fungous growth; wood then forms over the scars and we get a clean shaft which carries a crown high up beyond the reach of shade from neighbors.

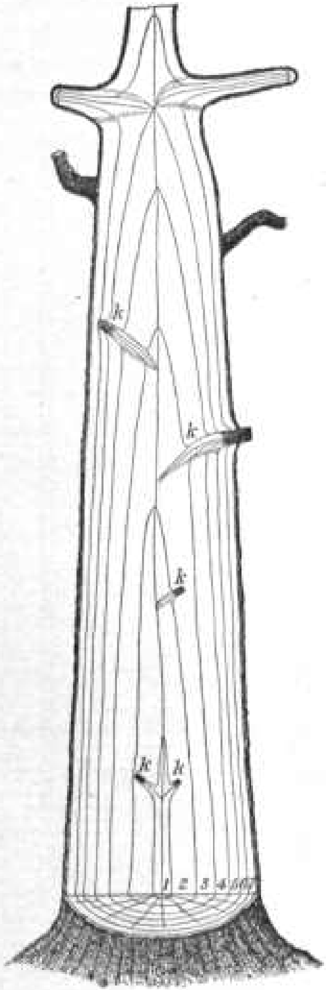


FIG. 10.—Scheme to illustrate the arrangement of annual growth. 1, 2, 3, etc., represent the parts of the stem grown during the first, second, third, etc., twenty years of the life of the tree. *k*, knots; the shaded part of each is the "dead knot" of lumber.

The branches being prevented from spreading out, the shaft is forced to grow upward, and hence, when crowded by others, trees become taller and more cylindrical in form, while in the open, where they can spread, they remain lower and more conical in form (figs. 11,12).

There are, to be sure, different natural types of development, some, like the walnuts, oaks, beeches, and the broad-leafed trees generally, having greater tendency to spread than others, like spruces, firs, and conifers in general, which lengthen their shaft in preference to spreading, even in the open. This tendency to spreading is also influenced by soil conditions and climate, as well as by the age of the tree. When the trees cease to grow in height, their crowns broaden, and this takes place sooner in shallow soils than in deep, moist ones; but the tendency can be checked and all can be made to develop the shaft at the expense of the branches by proper shading from the sides.

It follows that the forest planter, who desires to produce long and clean shafts and best working quality of timber, must secure and maintain side shade by a close stand, while the landscape gardener, who desires characteristic form, must maintain an open stand and full enjoyment of light for his trees.

Now, as we have seen, different species afford different amounts of shade, and in proportion to the shade which they afford can they endure shade. The beech or sugar maple or spruce, which maintain a large amount of foliage under the dense shade of their own crown, show that their leaves can live and functionate with a small amount of light. They are shade-enduring trees. On the other hand,

the black walnut, the locust, the catalpa, the poplars, and the larch show by the manner in which their crowns thin out, the foliage being confined to the ends of the branches, that their leaves require more light—they are light-needing trees; so that the scale which arranges the trees according to the amount of shade they exert serves also to measure their shade endurance.

In making, therefore, mixed plantations, the different kinds must be so grouped and managed that the shady trees will not outgrow and overtop the light-needing; the latter must either have the start of the former or must be quicker growers.

RATE OF GROWTH.

Not only do different species grow more or less rapidly in height and girth, but there is in each species a difference in the rate of growth during different periods of life, and a difference in the persistence of growth.

It stands to reason that trees grow differently in different soils and situations, and hence we can not compare different species with respect to their rate of growth except as they grow under the same conditions.

FIG. 11.—Oak tree grown in the open.

FIG. 12.—Maple tree grown in the forest.

Thus the black walnut may grow as fast as or faster than the ash on a rich, deep, moist, warm soil, but will soon fall to the rear in a wetter, colder, and shallower soil.

Given the same conditions, some species will start on a rapid upward growth at once, like the poplars, aspen, locust, and silver maple, making rapid progress (the most rapid from their tenth to their fifteenth year), but decreasing soon in rate and reaching their maximum height early. Others, like the spruce, beech, and sugar maple, will begin slowly, often occupying several, sometimes as many as 10 to 15, years before they appear to grow at all, their energy all going into root growth. Then comes a period of more and more accelerated growth, which reaches its maximum rate at 25 or 30 years; and when the cottonwood or aspen

has reached the end of its growth in height the spruce or pine is still at its best rate, and continues to grow for a long time at that rate; in later life the rate decreases, yet height growth sometimes does not cease altogether for centuries. As a rule, the light-needing species are the ones which show the rapid height growth at the start, while the shade-enduring are slow at the start, but persistent growers.

This fact is important in explaining the alternations of forest growth in nature; the persistent shade-enduring species crowd out the light-needing, and the latter rapidly take possession of any openings that fire or storm has made. It is also important with reference to the management of wood crops and starting of mixed plantations; the light-needing species must be mixed only with such shade-enduring species as are slower growers than themselves.

The diameter growth shows also periodic changes in its rate, and is, of course, influenced in the same way by soil, climate, and light conditions, as the height growth.

In the juvenile or brush stage, lasting 6 to 10 years in light-needing and 20 to 40 years in shade-enduring species, the diameter grows comparatively little, all energy being directed to height growth and root growth. When the crown has been definitely formed, more food material is available for wood formation, and the increase in foliage is accompanied by a more rapid increase of trunk diameter; in favorable situations, the highest rate occurs between the fortieth and sixtieth years; in the poorer situations, between the fiftieth and eightieth years, which rate continues for some time. Then comes a period of slower rate, which finally in old age dwindles down almost to zero.

But neither the diameter growth nor the width of the annual rings alone tells us directly what amount of wood is forming. The outer rings, being laid over a larger circumference, although thinner than the preceding rings, may yet have greater cubic contents. The statements of diameter growth are, therefore, misleading if we are interested in knowing how much wood is forming.

Accordingly the growth in volume must be considered separately, as determined by the enlargement of the cross-section area and the height. The growth in volume or mass accretion is quite small in young trees, so that when wood is cut young the smallest amount of crop per year is harvested, while, if it is allowed to grow, an increase more than proportionate to the number of years may be obtained.

Only when the tree has a fully developed crown does it begin to make much wood. Its volume growth progresses then at a uniform rate, and continues to do so for decades, and sometimes for a century or more.

On poorer sites the rate is slower, but remains longer on the increase, while on good sites the maximum rate is soon reached.

Of course, in a forest, where light conditions are not most favorable, because form development and soil conditions require shade, the total wood formation is less than in an isolated tree, favorably placed. Just

so the dominant trees in a forest—i. e., those which have their crowns above all others—show, of course, the advantage they have over the inferior trees which are suffering from the shade of their neighbors.

Finally, if we would take into consideration an entire forest growth, and determine, for instance, how much wood an acre of such forest produces at different periods, we must not overlook the fact that the number of trees per acre changes as the trees grow older. Some of them are overshaded and crowded out by the others, so that a young growth of spruce might start with 100,000 little seedlings to the acre, of which in the twentieth year only 10,000 would be alive, while in the fortieth year the number would be reduced to 1,200, and in the hundredth year to 280. Hence the rate of growth of any single tree gives no idea of what the acre of forest will do.

Thus, while a single good white pine might grow the fastest in volume when about one hundred years old, then making wood at the rate of, say, 1.5 cubic feet per year, an acre of pine on good soil, containing about 1,600 trees, may make the most wood in the thirtieth year, then growing at the rate of 170 cubic feet per acre, while in the hundredth year the rate would not exceed 70 cubic feet; and an acre of pine in a poorer location, with about 1,400 trees, may make the most wood in the fortieth year, at the rate of 100 cubic feet per acre.

From the consideration of the relation of light conditions to soil conditions, to form development, and to rate of growth, we may make the following deductions of interest to the forest planter:

In order to secure the best results in wood production, in quantity and quality, at the same time preserving favorable soil conditions, the forest should be composed of various species, a mixture of light-needing and shade-enduring kinds. The light-needing ones should be of quicker growth; the shady ones, in larger numbers, should be slower growers. For the first fifteen to twenty-five years the plantation should be kept as dense as possible, to secure clear shafts and good growth in height; then it should be thinned, to increase crown development and diameter growth; the thinning, however, is not to be so severe that the crowns can not close up again in two or three years; the thinning is to be repeated again and again, always favoring the best developed trees.

REPRODUCTION.

All trees reproduce themselves naturally from seed. Man can secure their reproduction also from cuttings or layers; and some kinds can reproduce themselves by shoots from the stump when the parent tree has been cut. This latter capacity is possessed in a varying degree by different species; chestnuts, oaks, elms, maples, poplars, and willows are most excellent sprouters; most conifers do not sprout at all, and the shoots of those that do sprout soon die (Sequoia or California redwood seems to be an exception). Sprouts of broad-leafed trees develop differently from seedlings, growing very rapidly at first, but soon lessening in the rate of growth and never attaining the height and perhaps not

the diameter of trees grown from the seed; they are also shorter lived. With age the stumps lose their capacity for sprouting. To secure best results, the parent tree should be cut close to the ground in early spring, avoiding severe frost, and a sharp cut should be made which will not sever the bark from the trunk.

Not all trees bear seed every year, and plentiful seed production, especially in a forest, occurs, as a rule, periodically. The periods differ with species, climate, and season.

Not all seeds can germinate, and in some species the number of seeds that can germinate is very small, and they lose their power of germination when kept a few hours, like the willows. Others, if kept till they have become dry, will "lie over" in the soil a year or more before germinating. The same thing will occur if they are covered too deep in the soil, provided they germinate at all under such conditions.

In order to germinate, seeds must have warmth, air, and moisture. The preparation of a seed bed is, therefore, necessary in order to supply these conditions in most favorable combination. In the natural forest millions of seeds rot or dry without sprouting, and millions of seedlings sprout, but soon perish under the too dense shade of the mother trees.

Man, desiring to reproduce a valuable wood crop, can not afford to be as lavish as nature, and must therefore improve upon nature's methods, making more careful preparation for the production of his crop, either by growing the seedlings in nurseries and transplanting them, or else by cutting away the old growth in such a manner as to secure to the young self-grown crop better chances for life and development.

2. HOW TO PLANT A FOREST.

Forest planting and tree planting are two different things. The orchardist, who plants for fruit; the landscape gardener, who plants for form; the roadside planter, who plants for shade, all have objects in view different from that of the forest planter, and therefore select and use their plant material differently. They deal with single individual trees, each one by itself destined for a definite purpose. The forester, on the other hand, plants a crop like the farmer; he deals not with the single seed or plant, but with masses of trees; the individual tree has value to him only as a part of the whole. It may come to harvest for its timber, or it may not come to harvest, and yet have answered its purpose as a part of the whole in shading the ground, or acting as nurse or "forwarder" as long as it was necessary.

His object is not to grow trees, but to produce wood, the largest amount of the best quality per acre, whether it be stored in one tree or in many, and his methods must be directed to that end.

As far as the manner of setting out plants or sowing seeds is concerned, the same general principles and the same care in manipulation are applicable as in any other planting, except as the cost of operating

on so large a scale may necessitate less careful methods than the gardener or nurseryman can afford to apply; the nearer, however, the performance of planting can be brought to the careful manner of the gardener, the surer the success. The principles underlying such methods have been discussed in the chapter "How trees grow;" in the present chapter it is proposed to point out briefly the special considerations which should guide the forest planter in particular.

WHAT TREES TO PLANT.

Adaptability to climate is the first requisite in the species to be planted.

It is best to choose from the native growth of the region which is known to be adapted to it. With regard to species not native, the reliance must be placed upon the experience of neighboring planters and upon experiment (at first on a small scale), after study of the requirements of the kinds proposed for trial.

Adaptation must be studied, not only with reference to temperature ranges and rainfall, but especially with reference to atmospheric humidity and requirements of transpiration.

Many species have a wide range of natural distribution, and hence of climatic adaptation. If such are to be used, it is important to secure seeds from that part of the range of natural distribution where the plants must be hardiest, i. e., the coldest and driest region in which it occurs, which insures hardy qualities in the offspring. For instance, the Douglas spruce from the humid and evenly tempered Pacific Slope will not be as hardy as that grown from seed collected on the dry and frigid slopes of the Rockies. Lack of attention to this requisite accounts for many failures. It must also be kept in mind that, while a species may be able to grow in another than its native climate, its wood may not there have the same valuable qualities which it develops in its native habitat.

Adaptability to soil must be studied less with reference to mineral constituents than to physical condition. Depth and moisture conditions, and the structure of the soil, which influences the movement of water in it, are the most important elements. While all trees thrive best in a moist to "fresh" soil of moderate depth (from 2 to 4 feet) and granular structure, some can adapt themselves to drier or wetter, shallow, and compact soils. Fissures in rocks into which the roots can penetrate often stand for depth of soil, and usually aid in maintaining favorable moisture conditions. In soils of great depth (i. e., from the surface to the impenetrable subsoil) and of coarse structure water may drain away so fast as not to be available to the roots.

Soil moisture must always be studied in conjunction with atmospheric moisture; for, while a species may thrive in an arid soil, when the demands of transpiration are not great, it may not do so when aridity

of atmosphere is added. Trees of the swamp are apt to be indifferent to soil moisture and to thrive quite well, if not better, in drier soils.

Adaptability to site.—While a species may be well adapted to the general climatic conditions of a region, and in general to the soil, there still remains to be considered its adaptability to the particular "site," under which term we may comprise the total effect of general climate, local climate, and soil. The general climatic conditions are locally influenced, especially by the slope, exposure, or aspect, and the surroundings. Thus we know that eastern exposures are more liable to frost, western exposures more liable to damage from winds, southern more apt to be hot and to dry out, and northern to be cooler and damper, having in consequence a shorter period of vegetation. Hollows and lowlands are more exposed to frosts and more subject to variations in soil moisture, etc.

Hence for these various situations it is advisable to select species which can best withstand such local dangers.

The use value, or utility, of the species is next to be considered. This must be done with reference to the commercial and domestic demand, and the length of time it takes the species to attain its value. The greater variety of purposes a wood may serve—i. e., the greater its general utility—and the sooner it attains its use value the better. White pine for the northeastern States as a wood is like the apple among fruits, making an all-round useful material in large quantities per acre in short time. Tulip poplar, applicable to a wider climatic range, is almost as valuable, while oak, ash, and hickory are standard woods in the market. Other woods are of limited application. Thus the black locust, which grows most quickly into useful posts, has only a limited market, much more limited than it should have; hickory soon furnishes valuable hoop poles from the thinnings, and later the best wagon material, not, however, large quantities in a short time; while black walnut of good quality is very high in price, the market is also limited, and the dark color of the heartwood, for which it is prized, is attained only by old trees. The black cherry, used for similar purposes, attains its value much sooner.

By planting various species together, variety of usefulness may be secured and the certainty of a market increased.

The forest value of the species is only in part expressed by its use value. As has been shown in another place, the composition of the crop must be such as to insure maintenance of favorable soil conditions, as well as satisfactory development of the crop itself. Some species, although of high use value, like ash, oak, etc., are poor preservers of soil conditions, allowing grass and weeds to enter the plantation and to deteriorate the soil under their thin foliage. Others, like beech, sugar maple, box elder, etc., although of less use value, being dense foliaged and preserving a shady crown for a long time, are of great forest value as soil improvers.

Again, as the value of logs depends largely on their freedom from knots, straightness, and length, it is of importance to secure these qualities. Some valuable species, if grown by themselves, make crooked trunks, do not clean their shafts of branches, and are apt to spread rather than lengthen. If planted in close companionship with others, they are forced by these "nurses or forwarders" to make better growths and clean their shafts of branches.

Furthermore, from financial considerations, it is well to know that some species develop more rapidly and produce larger quantities of useful material per acre than others; thus the white pine is a "big cropper," and, combining with this a tolerably good shading quality, and being in addition capable of easy reproduction, it is of highest "forest value."

Hence, as the object of forestry is to make money from continued wood crops, use value and forest value must both be considered in the selection of materials for forest planting.

Mutual relationship of different species, with reference especially to their relative height growth and their relative light requirements, must be considered in starting a mixed plantation.

Mixed forest plantations (made of several kinds) have so many advantages over pure plantations (made of one kind) that they should be preferred, except for very particular reasons. Mixed plantations are capable of producing larger quantities of better and more varied material, preserve soil conditions better, are less liable to damage from winds, fires, and insects, and can be more readily reproduced.

The following general rules should guide in making up the composition of a mixed plantation:

a. Shade-enduring kinds should form the bulk (five-eighths to seven-eighths) of the plantation, except on specially favored soils where no deterioration is to be feared from planting only light-needing kinds, and in which case these may even be planted by themselves.

b. The light-needing trees should be surrounded by shade-enduring of slower growth, so that the former may not be overtopped, but have the necessary light and be forced by side shade to straight growth.

c. Shade-enduring species may be grown in admixture with each other when their rate of height growth is about equal, or when the slower-growing kind can be protected against the quicker-growing (for instance, by planting a larger proportion of the former in groups or by cutting back the latter).

d. The more valuable timber trees which are to form the main crop should be so disposed individually, and planted in such numbers among the secondary crop or nurse crop, that the latter can be thinned out first without disturbing the former.

Where a plantation of light-foliaged trees has been made (black walnut, for instance), it can be greatly improved by "underplanting" densely with a shade-enduring kind, which will choke out weed growth, improve the soil, and thereby advance the growth of the plantation.

The selection and proper combination of species with reference to this mutual relationship to each other and to the soil are the most important elements of success.

Availability of the species also still needs consideration in this country; for, although a species may be very well adapted to the purpose in hand, it may be too difficult to obtain material for planting in quantity or at reasonable prices. While the beech is one of the best species for shade endurance, and hence for soil cover, seedlings can not be had as yet in quantity. Western conifers, although promising good material for forest planting, are at present too high priced for general use. Some eastern trees can be secured readily—either their seed or seedlings—from the native woods; others must be grown in nurseries before they can be placed in the field.

Whether to procure seeds or plants, and if the latter, what kind, depends upon a number of considerations. The main crop, that which is to furnish the better timber, had best be planted with nursery-grown plants, if of slow-growing kinds, perhaps once transplanted, with well-developed root systems, the plants in no case to be more than 2 to 3 years old. The secondary or nurse crop may then be sown or planted with younger and less costly material taken from the woods or grown in seed beds, or else cuttings may be used.

In some localities—for instance, the Western plains—the germinating of seeds in the open field is so uncertain, and the life of the young seedlings for the first year or two so precarious, that the use of seeds in the field can not be recommended. In such locations careful selection and treatment of the planting material according to the hardships which it must encounter can alone insure success.

Seedlings from 6 to 12 inches high furnish the best material. The planting of large-sized trees is not excluded, but is expensive and hence often impracticable, besides being less sure of success, since the larger-sized tree is apt to lose a greater proportion of its roots in transplanting.

METHODS OF PLANTING.

Preparation of soil is for the purpose of securing a favorable start for the young crop; its effects are lost after the first few years. Most land that is to be devoted to forest planting does not admit of as careful preparation as for agricultural crops, nor is it necessary where the climate is not too severe and the soil not too compact to prevent the young crop from establishing itself. Thousands of acres in Germany are planted annually without any soil preparation, yearling pine seedlings being set with a dibble in the unprepared ground. This absence of preparation is even necessary in sandy soils, like that encountered in the sandhills of Nebraska, which may, if disturbed, be blown out and shifted. In other cases a partial removal of a too rank undergrowth or soil cover and a shallow scarifying or hoeing is resorted to, or else furrows are thrown up and the trees set out in them.

In land that has been tilled, deep plowing (10 to 12 inches) and thorough pulverizing give the best chances for the young crop to start. For special conditions, very dry or very moist situations, special

methods are required. The best methods for planting in the semiarid regions of the far West have not yet been developed. Thorough cultivation, as for agricultural crops, with subsequent culture, is successful, but expensive. A plan which might be tried would consist in breaking the raw prairie in June and turning over a shallow sod, sowing a crop of oats or alfalfa, harvesting it with a high stubble, then opening furrows for planting and leaving the ground between furrows undisturbed, so as to secure the largest amount of drainage into the furrows and a mulch between the rows.

The time for planting depends on climatic and soil conditions and the convenience of the planter. Spring planting is preferable except in southern latitudes, especially in the West, where the winters are severe and the fall apt to be dry, the soil therefore not in favorable condition for planting.

The time for fall planting is after the leaves have fallen; for spring planting, before or just when life begins anew. In order to be ready in time for spring planting, it is a good practice to take up the plants in the fall and "heel them in" over winter (covering them, closely packed, in a dry trench of soil). Conifers can be planted later in spring and earlier in fall than broad-leafed trees.

The density of the trees is a matter in which most planters fail. The advantages of close planting lie in the quicker shading of the soil, hence the better preservation of its moisture and improved growth and form development of the crop. These advantages must be balanced against the increased cost of close planting. The closer the planting, the sooner will the plantation be self-sustaining and the surer the success.

If planted in squares, or, better still, in quincunx order (the trees in every other row alternating at equal distances), which is most desirable on account of the more systematic work possible and the more complete cover which it makes, the distance should not be more than 4 feet, unless for special reasons and conditions, while 2 feet apart is not too close, and still closer planting is done by nature with the best success.

The following numbers of trees per acre are required when planting at distances as indicated:

1½ by 1½ feet	19,360	2 by 4 feet	5,445
1½ by 2 feet	14,520	3 by 3 feet	4,840
2 by 2 feet	10,890	3 by 4 feet	3,630
2 by 3 feet	7,260	4 by 4 feet	2,722

To decrease expense, the bulk of the plantation may be made of the cheapest kinds of trees that may serve as soil cover and secondary or nurse crop, the main crop of from 300 to 600 trees to consist of better kinds, and with better planting material, mainly of light-needing species. These should be evenly disposed through the plantation, each closely surrounded by the nurse crop. It is, of course, understood that not all trees grow up; a constant change in numbers by the death (or else timely removal) of the overshaded takes place, so that the final crop shows at 100 years a close cover, with hardly 300 trees to the acre.

After-culture is not entirely avoidable, especially under unfavorable climatic conditions, and if the planting was not close enough. Shallow cultivation between the rows is needed to prevent weed growth and to keep the soil open, until it is shaded by the young trees, which may take a year with close planting and two or three years with rows 4 by 4 feet apart, the time varying also with the species.

It is rare that a plantation succeeds in all its parts; gaps or fail places occur, as a rule, and must be filled in by additional planting as soon as possible, if of larger extent than can be closed up in a few years by the neighboring growth.

When the soil is protected by a complete leaf canopy, the forest crop may be considered as established, and the after-treatment will consist of judicious thinning.

3. HOW TO TREAT THE WOOD LOT.

In the northeastern States it is the custom to have connected with the farm a piece of virgin woodland, commonly called the wood lot. Its object primarily is to supply the farmer with the firewood, fence material, and such dimension timbers as he may need from time to time for repairs on buildings, wagons, etc.

As a rule, the wood lot occupies, as it ought to, the poorer part of the farm, the rocky or stony, the dry or the wet portions, which are not well fitted for agricultural crops. As a rule, it is treated as it ought not to be, if the intention is to have it serve its purpose continuously; it is cut and culled without regard to its reproduction.

As far as firewood supplies go, the careful farmer will first use the dead and dying trees, broken limbs, and leavings, which is quite proper. The careless man avoids the extra labor which such material requires, and takes whatever splits best, no matter whether the material could be used for better purposes or not.

When it comes to the cutting of other material, fence rails, posts, or dimension timber, the general rule is to go into the lot and select the best trees of the best kind for the purpose. This looks at first sight like the natural, most practical way of doing. It is the method which the lumberman pursues when he "culls" the forest, and is, from his point of view perhaps, justifiable, for he only desires to secure at once what is most profitable in the forest. But for the farmer, who proposes to use his wood lot continuously for supplies of this kind, it is a method detrimental to his object, and in time it leaves him with a lot of poor, useless timber which encumbers the ground and prevents the growth of a better crop.

Our woods are mostly composed of many species of trees; they are mixed woods. Some of the species are valuable for some special purposes, others are applicable to a variety of purposes, and again others furnish but poor material for anything but firewood, and even for that use they may not be of the best.

Among the most valuable in the northeastern woods we should mention the white pine—king of all—the white ash, white and chestnut oak, hickories, tulip tree, black walnut, and black cherry, the last three being now nearly exhausted; next, spruce and hemlock, red pine, sugar maple, chestnut, various oaks of the black or red oak tribe, several species of ash and birch, black locust; lastly, elms and soft maples, basswood, poplars, and sycamore.

Now, by the common practice of culling the best it is evident that gradually all the best trees of the best kinds are taken out, leaving only inferior trees or inferior kinds—the weeds among trees, if one may call them such—and thus the wood lot becomes well-nigh useless.

It does not supply that for which it was intended; the soil, which was of little use for anything but a timber crop before, is still further deteriorated under this treatment, and being compacted by the constant running of cattle, the starting of a crop of seedlings is made nearly impossible. It would not pay to turn it into tillage ground or pasture; the farm has by so much lost in value. In other words, instead of using the interest on his capital, interest and capital have been used up together; the goose that laid the golden egg has been killed.

This is not necessary if only a little system is brought into the management of the wood lot and the smallest care is taken to avoid deterioration and secure reproduction.

IMPROVEMENT CUTTINGS.

The first care should be to improve the crop in its composition. Instead of culling it of its best material, it should be culled of its weeds, the poor kinds, which we do not care to reproduce, and which, like all other weeds, propagate themselves only too readily. This weeding must not, however, be done all at once, as it could be in a field crop, for in a full-grown piece of woodland each tree has a value, even the weed trees, as soil cover.

The great secret of success in all crop production lies in the regulating of water supplies; the manuring in part and the cultivating entirely, as well as drainage and irrigation, are means to this end. In forestry these means are usually not practicable, and hence other means are resorted to. The principal of these is to keep the soil as much as possible under cover, either by the shade which the foliage of the tall trees furnishes, or by that from the underbrush, or by the litter which accumulates and in decaying forms a humus cover, a most excellent mulch.

A combination of these three conditions, viz, a dense crown cover, woody underbrush where the crown cover is interrupted, and a heavy layer of well-decomposed humus, gives the best result. Under such conditions, first of all, the rain, being intercepted by the foliage and litter, reaches the ground only gradually, and therefore does not compact the soil as it does in the open field, but leaves it granular and open, so that the water can readily penetrate and move in the soil. Secondly, the surface evaporation is considerably reduced by the shade

and lack of air circulation in the dense woods, so that more moisture remains for the use of the trees. When the shade of the crowns overhead (the so-called "crown cover," or "canopy,") is perfect, but little undergrowth will be seen; but where the crown cover is interrupted or imperfect, an undergrowth will appear. If this is composed of young trees, or even shrubs, it is an advantage, but if of weeds, and especially grass, it is a misfortune, because these transpire a great deal more water than the woody plants and allow the soil to deteriorate in structure and therefore in water capacity.

Some weeds and grasses, to be sure, are capable of existing where but little light reaches the soil. When they appear it is a sign to the forester that he must be careful not to thin out the crown cover any more. When the more light-needing weeds and grasses appear it is a sign that too much light reaches the ground, and that the soil is already deteriorated. If this state continues, the heavy drain which the transpiration of these weeds makes upon the soil moisture, without any appreciable conservative action by their shade, will injure the soil still further.

The overhead shade or crown cover may be imperfect because there are not enough trees on the ground to close up the interspaces with their crowns, or else because the kinds of trees which make up the forest do not yield much shade; thus it can easily be observed that a beech, a sugar maple, a hemlock, is so densely foliaged that but little light reaches the soil through its crown canopy, while an ash, an oak, a larch, when full grown, in the forest, allows a good deal of light to penetrate.

Hence, in our weeding process for the improvement of the wood crop, we must be careful not to interrupt the crown cover too much, and thereby deteriorate the soil conditions. And for the same reason, in the selection of the kinds that are to be left or to be taken out, we shall not only consider their use value but also their shading value, trying to bring about such a mixture of shady and less shady kinds as will insure a continuously satisfactory crown cover, the shade-enduring kinds to occupy the lower stratum in the crown canopy, and to be more numerous than the light-needing.

The forester, therefore, watches first the conditions of his soil cover, and his next care is for the condition of the overhead shade, the "crown cover;" for a change in the condition of the latter brings change into his soil conditions, and, inversely, from the changes in the plant cover of the soil he judges whether he may or may not change the light conditions. The changes of the soil cover teach him more often when "to let alone" than when to go on with his operations of thinning out; that is to say, he can rarely stop short of that condition which is most favorable. Hence the improvement cuttings must be made with caution and only very gradually, so that no deterioration of the soil conditions be invited. We have repeated this injunction again and again, because

all success in the management of future wood crops depends upon the care bestowed upon the maintenance of favorable soil conditions.

As the object of this weeding is not only to remove the undesirable kinds from the present crop, but to prevent as much as possible their reappearance in subsequent crops, it may be advisable to cut such kinds as sprout readily from the stump in summer time—June or July—when the stumps are likely to die without sprouting.

It may take several years' cutting to bring the composition of the main crop into such a condition as to satisfy us.

METHODS OF REPRODUCING THE WOOD CROP.

Then comes the period of utilizing the main crop. As we propose to keep the wood lot as such, and desire to reproduce a satisfactory wood crop in place of the old one, this latter must be cut always with a view to that reproduction. There are various methods pursued for this purpose in large forestry operations which are not practicable on small areas, especially when these are expected to yield only small amounts of timber, and these little by little as required. It is possible, to be sure, to cut the entire crop and replant a new one, or else to use the ax skillfully and bring about a natural reproduction in a few years; but we want in the present case to lengthen out the period during which the old crop is cut, and hence must resort to other methods. There are three methods practicable.

We may clear narrow strips or bands entirely, expecting the neighboring growth to furnish the seed for covering the strip with a new crop—"the strip method;" or we can take out single trees here and there, relying again on an after-growth from seed shed by the surrounding trees—the "selection method;" or, finally, instead of single trees, we may cut entire groups of trees here and there in the same manner, the gaps to be filled, as in the other cases, with a young crop from the seed of the surrounding trees, and this we may call the "group method."

In *the strip method*, in order to secure sufficient seeding of the cleared strip, the latter must not be so broad that the seed from the neighboring growth can not be carried over it by the wind. In order to get the best results from the carrying power of the wind (as well as to avoid windfalls when the old growth is suddenly opened on the windward side) the strips should be located on the side opposite the prevailing winds. Oaks, beech, hickory, and nut trees in general with heavy seeds will not seed over any considerable breadth of strip, while with maple and ash the breadth may be made twice as great as the height of the timber, and the mother trees with lighter seeds, like spruce and pine, or birch and elm, may be able to cover strips of a breadth of 3 or 4 and even 8 times their height. But such broad strips are hazardous, since with insufficient seed fall, or fail years in the seed, the strip may remain exposed to sun and wind for several years without a good cover and deteriorate. It is safer, therefore, to make the strips no broader than just the height of the neighboring timber, in which case not only has the seed better

chance of covering the ground, but the soil and seedlings have more protection from the mother crop. In hilly country the strips must not be made in the direction of the slope, for the water would wash out soil and seed.

Every year, then, or from time to time, a new strip is to be cleared and "regenerated." But if the first strip failed to cover itself satisfactorily, the operation is stopped, for it would be unwise to remove the seed trees further by an additional clearing. Accordingly, this method should be

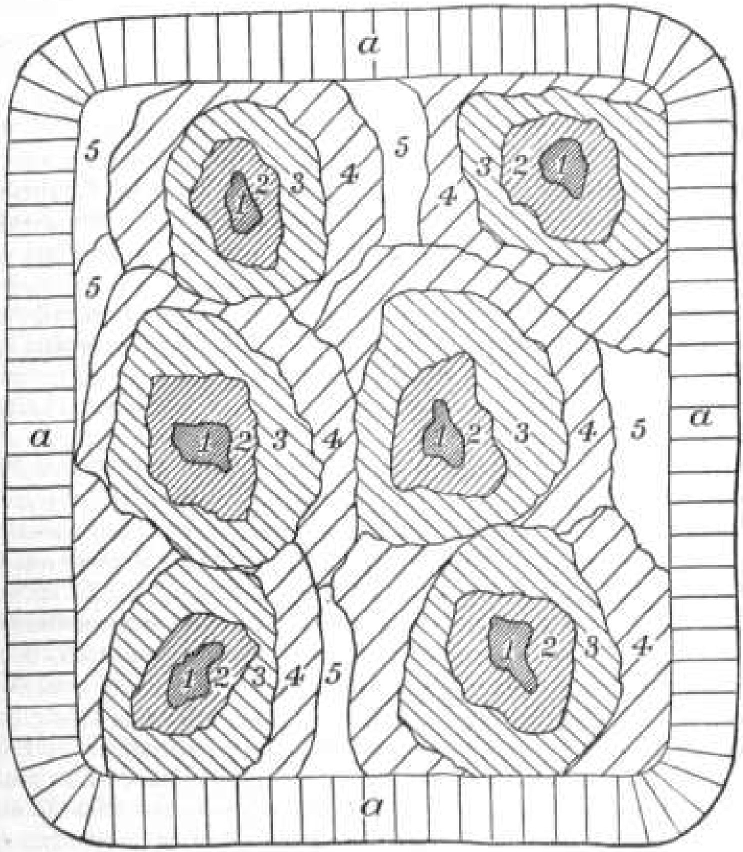


FIG. 13.—Showing plan of group system in regenerating a forest crop. 1, 2, 3, 4, successive groups of young timber, 1 being the oldest, 4 the youngest, 5 old timber; *a*, wind mantle, specially managed to secure protection.

used only where the kinds composing the mother crop are frequent and abundant seeders and give assurance of reseeding the strips quickly and successfully.

The other two methods have greater chances of success in that they preserve the soil conditions more surely, and there is more assurance of seeding from the neighboring trees on all sides.

The selection method, by which single trees are taken out all over the forest, is the same as has been practiced by the farmer and lumberman

hitherto, only they have forgotten to look after the young crop. Millions of seed may fall to the ground and germinate, but perish from the excessive shade of the mother trees. If we wish to be successful in establishing a new crop, it will be necessary to be ready with the ax all the time and give light as needed by the young crop. The openings made by taking out single trees are so small that there is great danger of the young crop being lost, or at least impeded in its development, because it is impracticable to come in time to its relief with the ax.

The best method, therefore, in all respects, is the "*group method*," which not only secures continuous soil cover, chances for full seeding, and more satisfactory light conditions, but requires less careful attention, or at least permits more freedom of movement and adaptation to local conditions (fig. 13).

It is especially adapted to mixed woods, as it permits securing for each species the most desirable light conditions by making the openings larger or smaller, according as the species we wish to favor in a particular group demand more or less shade. Further, when different species are ripe for regeneration at different times, this plan makes it possible to take them in hand as needed. Again, we can begin with one group or we can take in hand several groups simultaneously, as may be desirable and practicable.

We start our groups of new crop either where a young growth is already on the ground, enlarging around it, or where old timber has reached its highest usefulness and should be cut in order that we may not lose the larger growth which young trees would make; or else we choose a place which is but poorly stocked, where, if it is not regenerated, the soil is likely to deteriorate further. The choice is affected further by the consideration that dry situations should be taken in hand earlier than those in which the soil and site are more favorable, and that some species reach maturity and highest use value earlier than others and should therefore be reproduced earlier. In short, we begin the regeneration when and where the necessity for it exists, or where the young crop has the best chance to start most satisfactorily with the least artificial aid. Of course, advantage should be taken of the occurrence of seed years, which come at different intervals with different species.

If we begin with a group of young growth already on the ground, our plan is to remove gradually the old trees standing over them when no longer required for shade, and then to cut away the adjoining old growth and enlarge the opening in successive narrow bands around the young growth. When the first band has seeded itself satisfactorily, and the young growth has come to require more light (which may take several years), we remove another band around it, and thus the regeneration progresses. Where no young growth already exists, of course the first opening is made to afford a start, and afterwards the enlargement follows as occasion requires.

SIZE OF OPENINGS.

The size of the openings and the rapidity with which they should be enlarged vary, of course, with local conditions and the species which is to be favored, the light-needing species requiring larger openings and quicker light additions than the shade-enduring. It is difficult to give any rules, since the modifications due to local conditions are so manifold, requiring observation and judgment. Caution in not opening too much at a time and too quickly may avoid failure in securing good stands.

In general, the first openings may contain from one-fourth to one-half an acre or more, and the gradual enlarging may progress by clearing bands of a breadth not to exceed the height of the surrounding timber.

The time of the year when the cutting is to be done is naturally in winter, when the farmer has the most leisure, and when the wood seasons best after felling and is also most readily moved. Since it is expected that the seed fallen in the autumn will sprout in the spring, all wood should, of course, be removed from the seed ground.

The first opening, as well as the enlargement of the groups, should not be made at once, but by gradual thinning out, if the soil is not in good condition to receive and germinate the seed and it is impracticable to put it in such condition by artificial means—hoeing or plowing.

It is, of course, quite practicable—nay, sometimes very desirable—to prepare the soil for the reception and germination of the seed. Where undesirable undergrowth has started, it should be cut out, and where the soil is deteriorated with weed growth or compacted by the tramping of cattle, it should be hoed or otherwise scarified, so that the seed may find favorable conditions. To let pigs do the plowing and the covering of acorns is not an uncommon practice abroad.

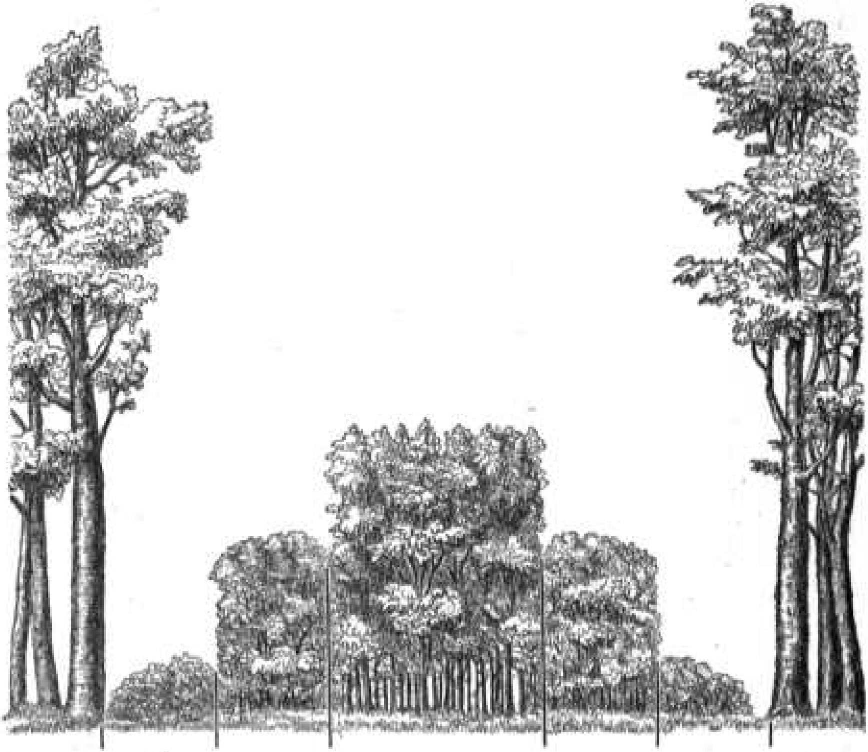
It is also quite proper, if the reproduction from the seed of the surrounding mother trees does not progress satisfactorily, to assist, when an opportunity is afforded, by planting such desirable species as were or were not in the composition of the original crop.

It may require ten, twenty, or forty years or more to secure the reproduction of a wood lot in this way. A new growth, denser and better than the old, with timber of varying age, will be the result. The progress of the regeneration in groups is shown on the accompanying plan, the different shadings showing the successive additions of young crop, the darkest denoting the oldest parts, first regenerated. If we should make a section through any one of the groups, this, ideally represented, would be like figure 14, the old growth on the outside, the youngest new crop adjoining it, and tiers of older growths of varying height toward the center of the group.

WIND MANTLE.

On the plan there will be noted a strip specially shaded, surrounding the entire plat (fig. 13, *a*), representing a strip of timber which should surround the farmer's wood lot, and which he should keep as dense as

possible, especially favoring undergrowth. This part, if practicable, should be kept reproduced as coppice or by the method of selection, i. e., by taking out trees here and there. When gaps are made, they should be filled, if possible, by introducing shade-enduring kinds, which, like the spruces and firs and beech, retain their branches down to the foot for a long time. This mantle is intended to protect the interior against the drying influence of winds, which are bound to enter the small wood lot and deteriorate the soil. The smaller the lot, the more necessary and desirable it is to maintain such a protective cover or windbreak.



Old timber. 3d. 2d. 1st cutting. 2d. 3d. Old timber.

FIG. 14.—Appearance of regeneration by group method.

COPPICE.

Besides reproducing a wood crop from the seed of mother trees or by planting, there is another reproduction possible by sprouts from the stump. This, to be sure, can be done only with broad-leafed species, since conifers, with but few exceptions, do not sprout from the stump. When a wood lot is cut over and over again, the reproduction taking place by such sprouts we call coppice.

Most wooded areas in the Eastern States have been so cut that reproduction from seed could not take place, and hence we have large areas

of coppice, with very few seedling trees interspersed. As we have seen in the chapter on "How trees grow," the sprouts do not develop into as good trees as the seedlings. They grow faster, to be sure, in the beginning, but do not grow as tall and are apt to be shorter lived.

For the production of firewood, fence, and post material, coppice management may suffice, but not for dimension timber. And even to keep the coppice in good reproductive condition, care should be taken to secure a certain proportion of seedling trees, since the old stumps, after repeated cutting, fail to sprout and die out.

Soil and climate influence the success of the coppice; shallow soils produce weaker but more numerous sprouts and are more readily deteriorated by the repeated laying bare of the soil; a mild climate is most favorable to a continuance of the reproductive power of the stump.

Some species sprout more readily than others; hence the composition of the crop will change, unless attention is paid to it. In the coppice, as in any other management of a natural wood crop, a desirable composition must first be secured, which is done by timely improvement cuttings, as described in a previous section.

The best trees for coppice in the northeastern States are the chestnut, various oaks, hickory, ash, elm, maples, basswood, and black locust, which are all good sprouters.

When cutting is done for reproduction, the time and manner are the main care. The best results are probably obtained, both financially and with regard to satisfactory reproduction, when the coppice is cut between the twentieth and thirtieth years. All cutting must be done in early spring or in winter, avoiding, however, days of severe frost, which is apt to sever the bark from the trunk and to kill the cambium. Cutting in summer kills the stump, as a rule. The cut should be made slanting downward, and as smooth as possible, to prevent collection of moisture on the stump and the resulting decay, and as close as possible to the ground, where the stump is less exposed to injuries, and the new sprouts, starting close to the ground, may strike independent roots.

Fail places or gaps should be filled by planting. This can be readily done by bending to the ground some of the neighboring sprouts, when 2 to 3 years old, notching, fastening them down with a wooden hook or a stone, and covering them with soil a short distance (4 to 6 inches) from the end. The sprout will then strike root, and after a year or so may be severed from the mother stock by a sharp cut (fig. 15).

For the recuperation of the crop, it is desirable to maintain a supply of seedling trees, which may be secured either by the natural seeding of a few mother trees of the old crop which are left, or by planting. This kind of management, coppice with seedling or standard trees intermixed, if the latter are left regularly and well distributed over the wood lot, leads to a management called "standard coppice." In this it is attempted to avoid the drawbacks of the coppice, viz, failure to produce dimension material and running out of the stocks. The former

object is, however, only partially accomplished, as the trees grown without sufficient side shading are apt to produce branchy boles and hence knotty timber, besides injuring the coppice by their shade.

PLAN OF MANAGEMENT.

In order to harmonize the requirements of the wood lot from a sylvicultural point of view, and the needs of the farmer for wood supplies, the cutting must follow some systematic plan.

The improvement cuttings need not, in point of time, have been made all over the lot before beginning the cuttings for regeneration, provided they have been made in those parts which are to be regenerated. Both the cuttings may go on simultaneously, and this enables the farmer to gauge the amount of cutting to his consumption. According to the

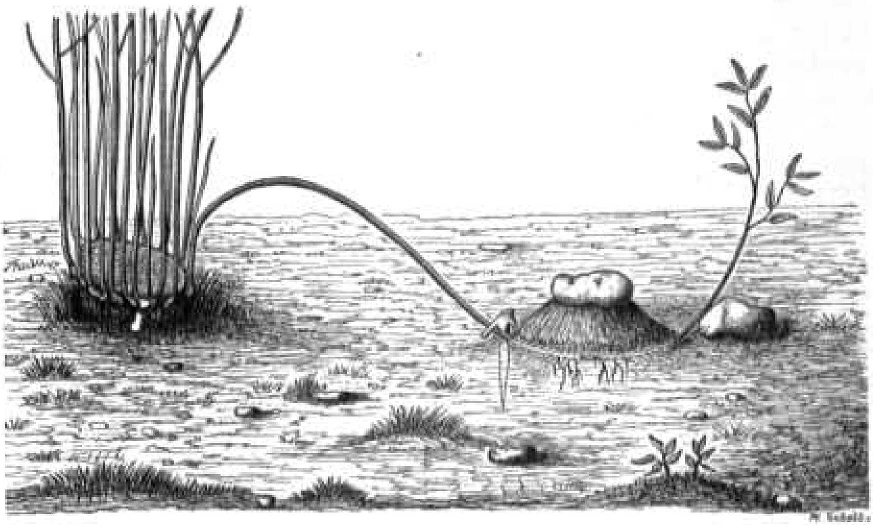


FIG. 15.—Method of layering to produce new stocks in coppice wood.

amount of wood needed, one or more groups may be started at the same time. It is, however, desirable, for the sake of renewing the crop systematically, to arrange the groups in a regular order over the lot.

4. HOW TO CULTIVATE THE WOOD CROP.

Where only firewood is desired, i. e., wood without special form, size, or quality, no attention to the crop is necessary, except to insure that it covers the ground completely. Nevertheless, even in such a crop, which is usually managed as coppice,[1] some of the operations described in this chapter may prove advantageous. Where, however, not only quantity but useful quality of the crop is also to be secured, the development of the wood crop may be advantageously influenced by controlling the supply of light available to the individual trees.

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[1] See page 35 for description of coppice.

It may be proper to repeat here briefly what has been explained in previous pages regarding the influence of light on tree development.

EFFECT OF LIGHT ON WOOD PRODUCTION.

Dense shade preserves soil moisture, the most essential element for wood production; a close stand of suitable kinds of trees secures this shading and prevents the surface evaporation of soil moisture, making it available for wood production. But a close stand also cuts off side light and confines the lateral growing space, and hence prevents the development of side branches and forces the growth energy of the soil to expend itself in height growth; the crown is carried up, and long, cylindrical shafts, clear of branches, are developed; a close stand thus secures desirable form and quality. Yet, since the quality of wood production or accretion (other things being equal) is in direct proportion to the amount of foliage and the available light, and since an open position promotes the development of a larger crown and of more foliage, an open stand tends to secure a larger amount of wood accretion on each tree. On the other hand, a tree grown in the open, besides producing more branches, deposits a larger proportion of wood at the base, so that the shape of the bole becomes more conical, a form which in sawing proves unprofitable; whereas a tree grown in the dense forest both lengthens its shaft at the expense of branch growth and makes a more even deposit of wood over the whole trunk, thus attaining a more cylindrical form. While, then, the total amount of wood production per acre may be as large in a close stand of trees as in an open one (within limits), the distribution of this amount among a larger or smaller number of individual trees produces different results in the quality of the crop. And since the size of a tree or log is important in determining its usefulness and value, the sooner the individual trees reach useful size, without suffering in other points of quality, the more profitable the whole crop.

NUMBER OF TREES PER ACRE.

The care of the forester, then, should be to maintain the smallest number of individuals on the ground which will secure the greatest amount of wood growth in the most desirable form of which the soil and climate are capable, without deteriorating the soil conditions. He tries to secure the most advantageous individual development of single trees without suffering the disadvantages resulting from too open stand. The solution of this problem requires the greatest skill and judgment, and rules can hardly be formulated with precision, since for every species or combination of species and conditions these rules must be modified.

In a well-established young crop the number of seedlings per acre varies greatly, from 3,000 to 100,000, according to soil, species, and the manner in which it originated, whether planted, sown, or seeded

naturally.[1] Left to themselves, the seedlings, as they develop, begin to crowd each other. At first this crowding results only in increasing the height growth and in preventing the spread and full development of side branches; by and by the lower branches failing to receive sufficient light finally die and break off—the shaft "clears itself." Then a distinct development of definite crowns takes place, and after some years a difference of height growth in different individuals becomes marked. Not a few trees fail to reach the general upper crown surface, and, being more or less overtopped, we can readily classify them according to height and development of crown, the superior or "dominating" ones growing more and more vigorously, the inferior or "dominated" trees falling more and more behind, and finally dying for lack of light, and thus a natural reduction in numbers, or thinning, takes place. This natural thinning goes on with varying rates at different ages continuing through the entire life of the crop, so that, while only 4,000 trees per acre may be required in the tenth year to make a dense crown cover or normally close stand, untouched by man, in the fortieth year 1,200 would suffice to make the same dense cover, in the eightieth year 350 would be a full stand, and in the one hundredth not more than 250, according to soil and species, more or less. As we can discern three stages in the development of a single tree—the juvenile, adolescent, and mature—so, in the development of a forest growth, we may distinguish three corresponding stages, namely, the "thicket" or brushwood, the "pole-wood" or sapling, and the "timber" stage. During the thicket stage, in which the trees have a bushy appearance, allowing hardly any distinction of stem and crown, the height growth is most rapid. This period may last, according to conditions and species, from 5 or 10 to 30 and even 40 years—longer on poor soils and with shade-enduring species, shorter with light-needing species on good soils—and, while it lasts, it is in the interest of the wood grower to maintain the close stand, which produces the long shaft, clear of branches, on which at a later period the wood that makes valuable, clear timber, may accumulate. Form development is now most important. The lower branches are to die and break off before they become too large. (See illustrations of the progress of "clearing," on pp. 15 and 16.) With light-needing species and with deciduous trees generally this dying off is accomplished more easily than with conifers. The spruces and even the white pine require very dense shading to "clear" the shaft. During this period it is only necessary to weed out the undesirable kinds, such as trees infested by insect and fungus, shrubs, sickly, stunted, or bushy trees which are apt to overtop and prevent the development of their better neighbors. In short, our attention is now devoted mainly to improving the composition of the crop.

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[1] If the crop does not, at 3 to 5 years of age, shade the ground well, with a complete crown cover, or canopy, it can not be said to be well established and should be filled out by planting.

WEEDING AND CLEANING THE CROP.

This weeding or cleaning is easily done with shears when the crop is from 3 to 5 years old. Later, mere cutting back of the undesirable trees with a knife or hatchet may be practiced. In well-made artificial plantations this weeding is rarely needed until about the eighth or tenth year. But in natural growths the young crop is sometimes so dense as to inordinately interfere with the development of the individual trees. The stems then remain so slender that there is danger of their being bent or broken by storm or snow when the growth is thinned out later. In such cases timely thinning is indicated to stimulate more rapid development of the rest of the crop. This can be done most cheaply by cutting swaths or lanes one yard wide and as far apart through the crop, leaving strips standing. The outer trees of the strip, at least, will then shoot ahead and become the main crop. These weeding or improvement cuttings, which must be made gradually and be repeated every two or three years, are best performed during the summer months, or in August and September, when it is easy to judge what should be taken out.

METHODS OF THINNING.

During the "thicket" stage, then, which may last from 10 to 25 and more years, the crop is gradually brought into proper composition and condition. When the "pole-wood" stage is reached, most of the saplings being now from 3 to 6 inches in diameter and from 15 to 25 feet in height, the variation in sizes and in appearance becomes more and more marked. Some of the taller trees begin to show a long, clear shaft and a definite crown. The trees can be more or less readily classified into height and size classes. The rate at which the height growth has progressed begins to fall off and diameter growth increases. Now comes the time when attention must be given to increasing this diameter growth by reducing the number of individuals and thus having all the wood which the soil can produce deposited on fewer individuals. This is done by judicious and often repeated thinning, taking out some of the trees and thereby giving more light and increasing the foliage of those remaining; and as the crowns expand, so do the trunks increase their diameter in direct proportion. These thinnings must, however, be made cautiously lest at the same time the soil is exposed too much, or the branch growth of those trees which are to become timber wood is too much stimulated. So varying are the conditions to be considered, according to soil, site, species, and development of the crop, that it is well-nigh impossible, without a long and detailed discussion, to lay down rules for the proper procedure. In addition the opinions of authorities differ largely both as to manner and degree of thinning, the old school advising moderate, and the new school severer thinnings.

For the farmer, who can give personal attention to detail and whose object is to grow a variety of sizes and kinds of wood, the following general method may perhaps be most useful:

First determine which trees are to be treated as the main crop or "final harvest" crop. For this 300 to 500 trees per acre of the best grown and most useful kinds may be selected, which should be distributed as uniformly as possible over the acre. These, then—or as many as may live till the final harvest—are destined to grow into timber and are to form the special favorites as much as possible. They may at first be marked to insure recognition; later on they will be readily distinguished by their superior development. The rest, which we will call the "subordinate" crop, is then to serve merely as filler, nurse, and soil cover.

WHAT TREES TO REMOVE.

It is now necessary, by careful observation of the surroundings of each of the "final harvest" crop trees, or "superiors," as we may call them, to determine what trees of the "subordinate" crop trees, or "inferiors," must be removed. All nurse trees that threaten to overtop the superiors must either be cut out or cut back and topped, if that is practicable, so that the crown of the superiors can develop freely. Those that are only narrowing in the superiors from the side, without preventing their free top development, need not be interfered with, especially while they are still useful in preventing the formation and spreading of side branches on the superiors. As soon as the latter have fully cleared their shafts, these crowding inferiors must be removed. Care must be taken, however, not to remove too many at a time, thus opening the crown cover too severely and thereby exposing the soil to the drying influence of the sun. Gradually, as the crowns of inferiors standing farther away begin to interfere with those of the superiors, the inferiors are removed, and thus the full effect of the light is secured in the accretion of the main harvest crop; at the same time the branch growth has been prevented and the soil has been kept shaded. Meanwhile thinnings may also be made in the subordinate crop, in order to secure also the most material from this part of the crop. This is done by cutting out all trees that threaten to be killed by their neighbors. In this way many a useful stick is saved and the dead material, only good for firewood, lessened. It is evident that trees which in the struggle for existence have fallen behind, so as to be overtopped by their neighbors, can not, either by their presence or by their removal, influence the remaining growth. They are removed only in order to utilize their wood before it decays.

It may be well to remark again that an undergrowth of woody plants interferes in no way with the development of the main crop, but, on the contrary, aids by its shade in preserving favorable moisture conditions. Its existence, however, shows in most cases that the crown cover is not

as dense as it should be, and hence that thinning is not required. Grass and weed growth, on the other hand, is emphatically disadvantageous and shows that the crown cover is dangerously open.

The answer to the three questions, When to begin the thinnings, How severely to thin, and How often to repeat the operation, must always depend upon the varying appearance of the growth and the necessities in each case. The first necessity for interference may arise with light-needing species as early as the twelfth or fifteenth year; with shade-enduring, not before the twentieth or twenty-fifth year. The necessary severity of the thinning and the repetition are somewhat interdependent. It is better to thin carefully and repeat the operation oftener than to open up so severely at once as to jeopardize the soil conditions. Especially in younger growths and on poorer soil, it is best never to open a continuous crown cover so that it could not close up again within 3 to 5 years; rather repeat the operation oftener. Later, when the trees have attained heights of 50 to 60 feet and clear boles (which may be in 40 to 50 years, according to soil and kind) the thinning may be more severe, so as to require repetition only every 6 to 10 years.

The condition of the crown cover, then, is the criterion which directs the ax. As soon as the crowns again touch or interlace, the time has arrived to thin again. In mixed growths it must not be overlooked that light-needing species must be specially protected against shadier neighbors. Shade-enduring trees, such as the spruces, beech, sugar maple, and hickories, bear overtopping for a time and will then grow vigorously when more light is given, while light-needing species, like the pines, larch, oaks, and ash, when once suppressed, may never be able to recover.

Particular attention is called to the necessity of leaving a rather denser "wind mantle" all around small groves. In this part of the grove the thinning must be less severe, unless coniferous trees on the outside can be encouraged by severe thinning to hold their branches low down, thus increasing their value as windbreaks.

The thinnings, then, while giving to the "final harvest" crop all the advantage of light for promoting its rapid development into serviceable timber size, furnish also better material from the subordinate crop. At 60 to 70 years of age the latter may have been entirely removed and only the originally selected "superiors" remain on the ground, or as many of them as have not died and been removed; 250 to 400 of these per acre will make a perfect stand of most valuable form and size, ready for the final harvest, which should be made as indicated in the preceding chapter.

5.—THE RELATION OF FORESTS TO FARMS.

That all things in nature are related to each other and interdependent is a common saying, a fact doubted by nobody, yet often forgotten or neglected in practical life. The reason is partly indifference and partly ignorance as to the actual nature of the relationship; hence we suffer, deservedly or not.

The farmer's business, more than any other, perhaps, depends for its success upon a true estimate of and careful regard for this interrelation. He adapts his crop to the nature of the soil, the manner of its cultivation to the changes of the seasons, and altogether he shapes conditions and places them in their proper relations to each other and adapts himself to them.

Soil, moisture, and heat are the three factors which, if properly related and utilized, combine to produce his crops. In some directions he can control these factors more or less readily; in others they are withdrawn from his immediate influence, and he is seemingly helpless. He can maintain the fertility of the soil by manuring, by proper rotation of crops, and by deep culture; he can remove surplus moisture by ditching and draining; he can, by irrigation systems, bring water to his crops, and by timely cultivation prevent excessive evaporation, thereby rendering more water available to the crop; but he can not control the rainfall nor the temperature changes of the seasons. Recent attempts to control the rainfall by direct means exhibit one of the greatest follies and misconceptions of natural forces we have witnessed during this age. Nevertheless, by indirect means the farmer has it in his power to exercise much greater control over these forces than he has attempted hitherto. He can prevent or reduce the unfavorable effects of temperature changes; he can increase the available water supplies, and prevent the evil effects of excessive rainfall; he can so manage the waters which fall as to get the most benefit from them and avoid the harm which they are able to inflict.

Before attempting to control the rainfall itself by artifice, we should study how to secure the best use of that which falls, as it comes within reach of human agencies and becomes available by natural causes.

How poorly we understand the use of these water supplies is evidenced yearly by destructive freshets and floods, with the accompanying washing of soil, followed by droughts, low waters, and deterioration of agricultural lands. It is claimed that annually in the United States about 200 square miles of fertile soil are washed into brooks and rivers, a loss of soil capital which can not be repaired for centuries. At the same time millions of dollars are appropriated yearly in the river and harbor bills to dig out the lost farms from the rivers, and many thousands of dollars' worth of crops and other property are destroyed by floods and overflows; not to count the large loss from

droughts which this country suffers yearly in one part or the other, and which, undoubtedly, could be largely avoided, if we knew how to manage the available water supplies.

The regulation, proper distribution, and utilization of the rain waters in humid as well as in arid regions—water management—is to be the great problem of successful agriculture in the future.

One of the most powerful means for such water management lies in the proper distribution and maintenance of forest areas. Nay, we can say that the most successful water management is not possible without forest management.

THE FOREST WATERS THE FARM.

Whether forests increase the amount of precipitation within or near their limits is still an open question, although there are indications that under certain conditions large, dense forest areas may have such an effect. At any rate, the water transpired by the foliage is certain, in some degree, to increase the relative humidity near the forest, and thereby increase directly or indirectly the water supplies in its neighborhood. This much we can assert, also, that while extended plains and fields, heated by the sun, and hence giving rise to warm currents of air, have the tendency to prevent condensation of the passing moisture-bearing currents, forest areas, with their cooler, moister air strata, do not have such a tendency, and local showers may therefore become more frequent in their neighborhood. But, though no increase in the amount of rainfall may be secured by forest areas, the availability of whatever falls is increased for the locality by a well-kept and properly located forest growth. The foliage, twigs, and branches break the fall of the raindrops, and so does the litter of the forest floor, hence the soil under this cover is not compacted as in the open field, but kept loose and granular, so that the water can readily penetrate and percolate; the water thus reaches the ground more slowly, dripping gradually from the leaves, branches, and trunks, and allowing more time for it to sink into the soil. This percolation is also made easier by the channels along the many roots. Similarly, on account of the open structure of the soil and the slower melting of the snow under a forest cover in spring, where it lies a fortnight to a month longer than in exposed positions and melts with less waste from evaporation, the snow waters more fully penetrate the ground. Again, more snow is caught and preserved under the forest cover than on the wind-swept fields and prairies.

All these conditions operate together, with the result that larger amounts of the water sink into the forest soil and to greater depths than in open fields. This moisture is conserved because of the reduced evaporation in the cool and still forest air, being protected from the two great moisture-dissipating agents, sun and wind. By these conditions alone the water supplies available in the soil are increased from

50 to 60 per cent over those available on the open field. Owing to these two causes, then—increased percolation and decreased evaporation—larger amounts of moisture become available to feed the springs and subsoil waters, and these become finally available to the farm, if the forest is located at a higher elevation than the field. The great importance of the subsoil water especially and the influence of forest areas upon it has so far received too little attention and appreciation. It is the subsoil water that is capable of supplying the needed moisture in times of drought.

THE FOREST TEMPERS THE FARM.

Another method by which a forest belt becomes a conservator of moisture lies in its wind-breaking capacity, by which both velocity and temperature of winds are modified and evaporation from the fields to the leeward is reduced.

On the prairie, wind swept every day and every hour, the farmer has learned to plant a wind-break around his buildings and orchards, often only a single row of trees, and finds even that a desirable shelter, tempering both the hot winds of summer and the cold blasts of winter. The fields he usually leaves unprotected; yet a wind-break around his crops to the windward would bring him increased yield, and a timber belt would act still more effectively. Says a farmer from Illinois:

> My experience is that now in cold and stormy winters fields protected by timber belts yield full crops, while fields not protected yield only one-third of a crop. Twenty-five or thirty years ago we never had any wheat killed by winter frost, and every year we had a full crop of peaches, which is now very rare. At that time we had plenty of timber around our fields and orchards, now cleared away.

Not only is the temperature of the winds modified by passing over and through the shaded and cooler spaces of protecting timber belts disposed toward the windward and alternating with the fields, but their velocity is broken and moderated, and since with reduced velocity the evaporative power of the winds is very greatly reduced, so more water is left available for crops. Every foot in height of a forest growth will protect 1 rod in distance, and several belts in succession would probably greatly increase the effective distance. By preventing deep freezing of the soil the winter cold is not so much prolonged, and the frequent fogs and mists that hover near forest areas prevent many frosts. That stock will thrive better where it can find protection from the cold blasts of winter and from the heat of the sun in summer is a well-established fact.

THE FOREST PROTECTS THE FARM.

On the sandy plains, where the winds are apt to blow the sand, shifting it hither and thither, a forest belt to the windward is the only means to keep the farm protected.

In the mountain and hill country the farms are apt to suffer from heavy rains washing away the soil. Where the tops and slopes are bared of their forest cover, the litter of the forest floor burnt up, the soil trampled and compacted by cattle and by the patter of the raindrops, the water can not penetrate the soil readily, but is carried off superficially, especially when the soil is of clay and naturally compact. As a result the waters, rushing over the surface down the hill, run together in rivulets and streams and acquire such a force as to be able to move loose particles and even stones; the ground becomes furrowed with gullies and runs; the fertile soil is washed away; the fields below are covered with silt; the roads are damaged; the water courses tear their banks, and later run dry because the waters that should feed them by subterranean channels have been carried away in the flood.

The forest cover on the hilltops and steep hillsides which are not fit for cultivation prevents this erosive action of the waters by the same influence by which it increases available water supplies. The important effects of a forest cover, then, are retention of larger quantities of water and carrying them off under ground and giving them up gradually, thus extending the time of their usefulness and preventing their destructive action.

In order to be thoroughly effective, the forest growth must be dense, and, especially, the forest floor must not be robbed of its accumulations of foliage, surface mulch and litter, or its underbrush by fire, nor must it be compacted by the trampling of cattle.

On the gentler slopes, which are devoted to cultivation, methods of underdraining, such as horizontal ditches partly filled with stones and covered with soil, terracing, and contour plowing, deep cultivation, sodding, and proper rotation of crops, must be employed to prevent damage from surface waters.

THE FOREST SUPPLIES THE FARM WITH USEFUL MATERIAL.

All the benefits derived from the favorable influence of forest belts upon water conditions can be had without losing any of the useful material that the forest produces. The forest grows to be cut and to be utilized; it is a crop to be harvested. It is a crop which, if properly managed, does not need to be replanted; it reproduces itself.

When once established, the ax, if properly guided by skillful hands, is the only tool necessary to cultivate it and to reproduce it. There is no necessity of planting unless the wood lot has been mismanaged.

The wood lot, then, if properly managed, is not only the guardian of the farm, but it is the savings bank from which fair interest can be annually drawn, utilizing for the purpose the poorest part of the farm. Nor does the wood lot require much attention; it is to the farm what the workbasket is to the good housewife—a means with which to

improve the odds and ends of time, especially during the winter, when other farm business is at a standstill.

It may be added that the material which the farmer can secure from the wood lot, besides the other advantages recited above, is of far greater importance and value than is generally admitted.

On a well-regulated farm of 160 acres, with its 4 miles and more of fencing and with its wood fires in range and stove, at least 25 cords of wood are required annually, besides material for repair of buildings, or altogether the annual product of probably 40 to 50 acres of well-stocked forest is needed. The product may represent, according to location, an actual stumpage value of from $1 to $3 per acre, a sure crop coming every year without regard to weather, without trouble and work, and raised on the poorest part of the farm. It is questionable whether such net results could be secured with the same steadiness from any other crop. Nor must it be overlooked that the work in harvesting this crop falls into a time when little else could be done.

Wire fences and coal fires are, no doubt, good substitutes, but they require ready cash, and often the distance of haulage makes them rather expensive. Presently, too, when the virgin woods have been still further culled of their valuable stores, the farmer who has preserved a sufficiently large and well-tended wood lot will be able to derive a comfortable money revenue from it by supplying the market with wood of various kinds and sizes. The German State forests, with their complicated administrations, which eat up 4 per cent of the gross income, yield, with prices of wood about the same as in our country, an annual net revenue of from $1 to $4 and more per acre. Why should not the farmer, who does not pay salaries to managers, overseers, and forest guards, make at least as much money out of this crop when he is within reach of a market?

With varying conditions the methods would of course vary. In a general way, if he happens to have a virgin growth of mixed woods, the first care would be to improve the composition of the wood lot by cutting out the less desirable kinds, the weeds of tree growth, and the poorly grown trees which impede the development of more deserving neighbors.

The wood thus cut he will use as firewood or in any other way, and, even if he could not use it at all, and had to burn it up, the operation would pay indirectly by leaving him a better crop. Then he may use the rest of the crop, gradually cutting the trees as needed, but he must take care that the openings are not made too large, so that they can readily fill out with young growth from the seed of the remaining trees, and he must also pay attention to the young aftergrowth, giving it light as needed. Thus without ever resorting to planting he may harvest the old timber and have a new crop taking its place and perpetuate the wood lot without in any way curtailing his use of the same.

FARMERS' BULLETINS.

These bulletins are sent free of charge to any address upon application to the Secretary of Agriculture, Washington, D. C. Only the following are available for distribution:

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No. 19. Important Insecticides: Directions for Their Preparation and Use. Pp. 20.
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